THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

BULLETIN No. 13

ALAMEDA COUNTY INVESTIGATION

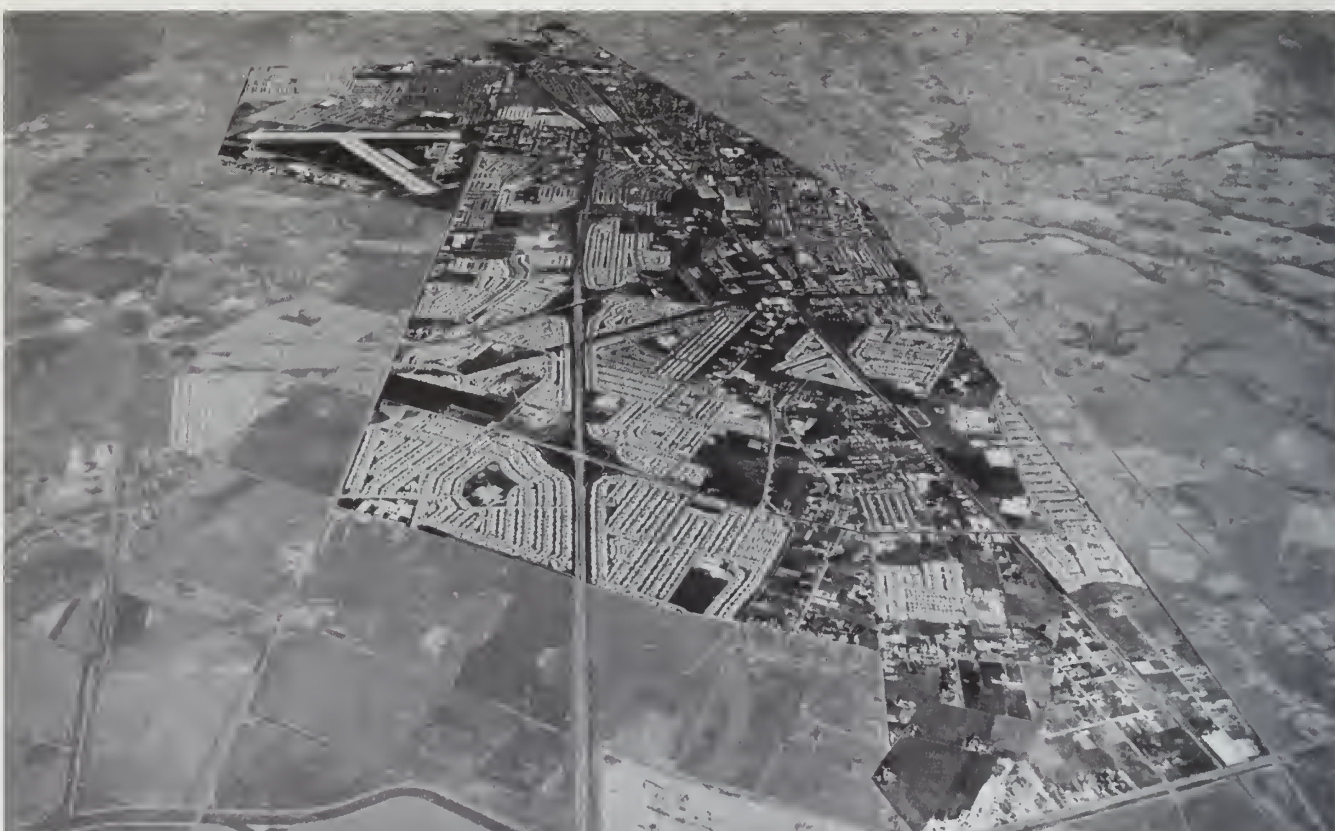
MARCH 1963

HUGO FISHER
Administrator
The Resources Agency of California

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

URBAN DEVELOPMENT IN HAYWARD AREA
MARCH 1952



Aerial Photographs Courtesy
Alameda County Flood Control and
Water Conservation District

URBAN DEVELOPMENT IN HAYWARD AREA
DECEMBER 1960

State of California
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Department of Water Resources

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FOREWORD

The investigation reported in this bulletin was initiated in 1949 under cooperative agreements with Alameda County and the former State Division of Water Resources. Subsequent to publication of a preliminary edition of Bulletin No. 13 in July 1955, additional basic data on water resources have been collected by various agencies, studies have been made of ground water quality problems in the area, and the South Bay Aqueduct of the State Water Facilities has been partially completed and is now serving water in Alameda County.

This bulletin is basically a final report on the field investigations made during 1949-51, although several revisions have been made to the preliminary edition to reflect more current data, recent studies, and the present conditions of water supply developemnt. Records of precipitation and runoff through 1960 are included for information. Projections of population and increased water use have been revised to reflect forecasts utilized in contracts for water service from the South Bay Aqueduct. Data on water deliveries by local agencies have been brought up-to-date. Additional knowledge gathered during recent investigations of ground water conditions and water quality have been incorporated. Alternative plans for local development described in the preliminary edition have been modified to reflect the construction program of the San Frencisco Water Department for San Antonio Dam in Alameda County and the operation of the South Bay Aqueduct.

Although several modifications to the preliminary edition have been made to reflect current conditions, it has not been possible within the scope of the funds available for publishing this report to make a full re-evaluation of the present water uses and the overdrafts in the ground water basins. The estimates of future supplemental water requirements have been based upon estimates of water supply as determined at the time of the field investigations. It should be noted that the present supplemental water requirements and those which will occur during the next three decades will be met by water imported through the South Bay Aqueduct, the Hetch Hetchy Aqueduct, and the facilities of the East Bay Municipal Utility District.

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THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
1120 N STREET, SACRAMENTO

January 28, 1963

Honorable Edmund G. Brown, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 13, "Alameda County Investigation." Investigations leading to the preparation of this bulletin were conducted for the Water Resources Board by the former Division of Water Resources in 1949, 1950, and 1951, and a preliminary report was published by the Water Resources Board in 1955. Pursuant to contracts between the Department of Water Resources and the Alameda County Flood Control and Water Conservation District, the department has updated the preliminary report to reflect recent data.

The principal conclusion set forth in Bulletin No. 13 is that the basic water problem in Alameda County is the perennial overdraft on the ground water basin. It is further concluded that the need for supplemental water in the immediate future can be met largely by importation of water via the South Bay Aqueduct.

Sincerely yours,

William E. Warne

Director

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

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CHAPTER I. INTRODUCTION

Certain portions of Alameda County, in common with many other parts of California, have experienced rapid increases in water utilization, and as a result are confronted with an urgent need for development of supplemental water supplies. An accelerated increase in ground water use, combined with deficient water supply during recent years has resulted in progressive lowering of ground water levels and deterioration in quality of water at a number of wells. This situation has brought about local concern regarding the adequacy of the ground water resources of Alameda County.

Authorization for Investigation

In consideration of the adverse ground water situation in Alameda County, representatives of local interests in the Livermore Valley and southern Alameda County appeared before the State Water Resources Board at Sacramento on March 5, 1948, and September 2, 1949, respectively, and requested state-county cooperative surveys of ground water supplies of each of these areas. The board referred the requests to the State Engineer for preliminary examination and report on the need for such investigations, and estimates of their scope, duration, and cost.

The State Water Resources Board, on May 10, 1948, approved a recommendation by the State Engineer, based on findings of a preliminary examination, for a two-year cooperative investigation of Livermore Valley, and authorized negotiation of an agreement with local agencies. The agreement between the State Water Resources Board, the County of Alameda, and the State Department of Public Works acting through the agency of the State Engineer, was executed on September 17, 1948. It provided that the work to be performed

> "shall consist of investigation and report on the underground water supply in Livermore Valley, in the County of Alameda, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the water problems involved."

This agreement authorized the provision of funds to meet the costs of investigation for one year. A supplemental agreement executed by the same parties on October 15, 1949, authorized funds to complete the investigation and report. Funds to meet the costs of the investigation and report in the amount of $19,000 were provided as follows: State of California (State Water Resources Board), $9,500; and County of Alameda, $9,500.

On September 2, 1949, the State Water Resources Board approved a recommendation by the State Engineer, based on findings of a preliminary examination, for a similar two-year cooperative investigation of southern Alameda County and authorized negotiation of an agreement with local agencies. This agreement, between the State Water Resources Board, the County of Alameda, and State Department of Public Works acting through the agency of the State Engineer, was executed on December 1, 1949. It provided that the work to be performed

> "shall consist of an investigation and report on the ground water supply in southern Alameda County, including location, replenishment, quality and utilization thereof, and, if possible, a method or methods of solving the water problems involved."

This agreement authorized the provision of funds to meet the costs of investigation for one year. A supplemental agreement executed by the same parties on December 1, 1950, authorized funds to complete the investigation and report. Funds to meet the costs of the investigation and report in the amount of $50,000 were provided as follows: State of California (State Water Resources Board), $25,000; and County of Alameda, $25,000.

Inasmuch as the foregoing two investigations were implemented by contracts between the same agencies, and the investigational areas as defined in the agreements are contiguous, the two areas have been combined for consideration in this bulletin into one area designated the "Alameda County Area." The two investigations are hereinafter referred to collectively as the "Alameda County Investigation." Combined reporting of the investigations was concurred in by the several parties to the agreements.

Additional funds were expended in investigation of the Alameda County Area by the State Water Resources Board in connection with the Statewide Water Resources Investigation, certain results of which have been used in connection with the Alameda County Investigation. Ninety-five copies of a preliminary edition of Bulletin No. 13, "Alameda County Investigation," were published in July 1955.

Effective on July 5, 1956, pursuant to Chapter 52, Statutes of 1956, the State Department of Water Resources was created. The department succeeded to, and was vested with, all of the powers, duties, purposes, responsibilities, and jurisdiction in matters pertaining to water formerly vested in the Division of Water Resources of the Department of Public Works, the State Engineer, and the State Water Resources Board. In particular, the authority and responsibilities of the board relative to the Alameda County Investigation and preparation of this bulletin were then and have since been vested wholly in the Department of Water Resources.

In 1952, the Alameda County Flood Control and Water Conservation District was designated by the County of Alameda to act for the county in matters pertaining to water resources planning. In January 1961, the State Department of Water Resources entered into a contract with the Alameda County Flood Control and Water Conservation District wherein the State agreed to update the data and publish the report of the Alameda County Investigation. Costs, to a total of $10,000, would be shared equally by both parties to the agreement.

Copies of the agreements of 1948 and 1949 and their supplements and a copy of the agreement of January 1961 are included as Appendix A.

Related Investigations and Reports

The following reports of prior investigations, containing information pertinent to evaluation of water problems in the Alameda County Area, were reviewed in connection with the current investigations:

Alameda County Flood Control and Water Conservation District. "Water Supply for Southern Alameda County, Hayward, Fremont, Newark, and Union City, Through Proposed Zone 8." June 1961.

Alameda County Water District. "Comparison of Supplemental Sources of Water Supply." May 1961.

Bailey, Paul. "Engineers' Report on Investigations on the Niles Cone, 1916-1920" State Water Commission of 1916. May 1920.

Binkley, T. C. "Investigation and Report on Feasibility of Water Service to the Sunol-Kilkare Woods Area for the Pleasanton Township County Water District." April 1961.

California State Department of Public Works, Division of Water Resources. "Ground Water Basins in California." Water Quality Investigations Report No. 3. November, 1952.

----. "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan." February 1955.

California State Water Project Authority. "Report to the California State Legislature on Feasibility of Construction by the State of Barriers in the San Francisco Bay System." March 1955.

California State Water Resources Board. "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan." May 1951.

----. "Water Resources of California." Bulletin No. 1. 1951.

----. "Water Utilization and Requirements of California." Bulletin No. 2. June 1955.

----. "Santa Clara Valley Investigation." Bulletin No. 7. June 1955.

California State Department of Water Resources. "The California Water Plan." Bulletin No. 3. 1957.

----. "Interim Report to the California State Legislature on the Salinity Control Barrier Investigation." Bulletin No. 60. 1957.

----. "Dams Within Jurisdiction of State of California." Bulletin No. 17. 1958.

----. "Intrusion of Salt Water into Ground Water Basins of Southern Alameda County." Bulletin No. 81. 1960.

California State Water Project Authority. "Feasibility of Construction by the State of Barriers in the San Francisco Bay System." March 1955.

Clark, W. O. "Ground-Water Resources of the Niles Cone and Adjacent Areas, California." United States Geological Survey Water-Supply Paper 345-H. 1915.

Engineering-Science, Inc. "Water Requirements of the City of Fremont, California." May 1960.

Espy, T. W. "Arroyo del Valle Creek Flood Control and Water Supply for Alameda County Water District." April 1948.

Flaa, I. E. "San Antonio Creek Water Supply for Alameda County Water District." July 1947.

Freeman, John R. "The Hetch Hetchy Water Supply for San Francisco." City of San Francisco. 1912.

Hall, L. Standish. "Alameda Creek." March 1926.

Harding, J. M., Jr. "The Geology of the Southern Part of the Pleasanton Quadrangle, California." Master's Thesis. University of California. 1942.

Herrmann, F. C. "The Future Water Supply of San Francisco, Spring Valley Water Company." 1912.

Homes, L. C. and Nelson, J. W. "Reconnaissance Soil Survey of the San Francisco Bay Region, California." United States Department of Agriculture, Bureau of Soils. 1917.

Kennedy Engineers. "Report on Eastern Alameda County Sewage and Industrial Wastes for the County of Alameda, California." December 1960.

Lee, Charles H. "The Future Development of the Metropolitan Area Surrounding San Francisco Bay." Bulletin of the Seismological Society of America, Vol. XVI, No. 2. June 1926.

San Francisco Public Utilities Commission. Annual Reports.

Smith, M. B. "Ground Water in the Livermore Valley, California." Master's Thesis. Stanford University. 1934.

Snow, D. T. "Geology of the Northeast Corner of Alameda County and Adjacent Portions of Contra Costa." Master's Thesis. University of California. 1956.

United States Department of the Army, Corps of Engineers, San Francisco District. "Preliminary Examination Report for Flood Control, Alameda Creek, California. February 10, 1942.

----. "Report on Alameda Creek, California." November 1961.

----. "Review of Report on San Lorenzo Creek, Alameda County, California, for Flood Control and Allied Purposes." February 18, 1953.

----. "San Francisco Bay Study, Basic Data Book." June 1, 1958.

West, C. H. "Ground Water Resources of the Niles Cone, Alameda County, California." November 1937.

Westover, H. L. and Van Duyne, C. "Soil Survey of the Livermore Area, California." United States Department of Agriculture, Bureau of Soils. 1911.

Williams, Cyril. "Report on Water Supply of Alameda Creek Watershed With Particular Reference to Livermore Valley Underground Supply." Unpublished report. 1912.

Objectives of Investigation

It has been stated that under provisions of the authorizing agreements the general objectives of the Alameda County Investigation included investigation and study of the underground water supply in the investigational area, including quality, replenishment, and utilization thereof, and if possible, a method or methods of solving the water problems involved. In attaining these objectives it was necessary that the scope of the investigation include full consideration of surface as well as ground water supplies, and that it involve determination of present and probable ultimate water utilization and supplemental water requirements.

Scope of Investigation

Field work in the Alameda County Area and office studies, as authorized by the initial and supplemental agreements, commenced in October 1948, and July 1949, on Livermore Valley and southern Alameda County, respectively. Intermittent field work was continued into 1953.

In the course of the Alameda County Investigation, available precipitation and stream flow records were collected and compiled in order to evaluate water supplies available to the Alameda County Area. Fifteen stream gaging stations were installed and maintained to supplement available hydrographic data. These stations were established in the Livermore Valley on Arroyo del Valle, Arroyo Mocho, Arroyo las Positas, Alamo Creek, Tassajara Creek, and Arroyo de la Laguna; in Sunol Valley on San Antonio Creek; and in southern Alameda County on Dry Creek at Highway 9 and at Nursery Road, Patterson Slough, San Lorenzo Creek at Hayward Union High School and at Lorenzo Avenue, Alameda Creek near Alvarado and at Shinn Pit, and San Leandro Creek.

In order to determine ground water storage capacity and yield, geologic features of the ground water basins underlying the Alameda County Area were investigated. This survey included the collection and study of about 350 well logs. The effects of draft on and replenishment of the ground water basin were determined by measurements of static ground water levels made at about 450 wells during each spring and fall during the period of investigation. These wells were chosen to form a comprehensive grid over the entire area. In addition, measurements to determine monthly fluctuations of water levels were made at approximately 130 control wells.

Complete surveys of the uses of valley floor lands were conducted in 1949 and 1951 in the Livermore and Sunol Valleys, and in 1949, 1950, and 1951 in southern

Alameda County. The total area surveyed embraced about 106,000 acres, exclusive of some 23,200 acres of salt ponds and tidelands along the easterly shore of the bay. The land use survey data were used in conjunction with available data on unit water use to determine total water requirements in the investigational areas in 1951.

In order to determine future water requirements, the pattern of land use was projected to the year 1990 and to probable ultimate development. Lands were segregated into urban and agricultural classes, and agricultural lands were further classified with regard to their relative suitability for irrigated crops by means of a land classification survey.

Irrigation practices in the Alameda County Area were surveyed to determine unit application of water to important crops on lands of various soil types. Records of application of water were collected at 20 plots during the 1949 irrigation season, at 28 plots during the 1950 season, and at 21 plots during the 1951 season. The data collected included records of pump discharge, acreage served, crops irrigated, number and period of irrigations, and amount of water applied.

Studies were made of the mineral quality of surface and ground water to evaluate their suitability for beneficial uses. Data used in these studies included 333 partial and 251 complete mineral analyses of ground water. In addition, a large number of analyses of surface water supplies were collected and studied.

Field reconnaissance surveys, including geologic examinations, were made to locate and evaluate possible dam and reservoir sites. Reconnaissance surveys were also made of possible routes for conveyance of water to areas of use.

Area of Investigation

The area of investigation, as set forth in the foregoing agreements, embraces all the drainage area within Alameda County tributary to San Francisco Bay between San Leandro Creek on the north and Coyote Creek on the south. However, for hydrologic purposes it has been necessary to consider also the tributary drainage areas in Contra Costa and Santa Clara Counties. Since the portion of the San Leandro Creek drainage area included in the investigated area, as defined in the agreements, is an incomplete hydrologic unit, and since San Leandro Creek is highly developed by the East Bay Municipal Utility District, that area has been excluded from the investigation. Moreover, the district provides substantially all the present water service in that area, and plans to provide its future water requirements.

The Alameda County Area is located east of and adjacent to the southern arm of San Francisco Bay, and is largely in the Diablo Range of the Coast Range Mountains. There are three main ground water basins in the area. These are the Livermore and Sunol Valleys, both within the Diablo Range, and the alluvial plain along the easterly shore of San Francisco Bay. Livermore Valley is about 14 miles long in an east-west direction and varies from 3 to 6 miles in width. Sunol Valley is a small valley about 6 miles south of Pleasanton at the confluence of Arroyo de la Laguna and San Antonio and Alameda Creeks. The alluvial land along the southern arm of San Francisco Bay is about 20 miles long and averages about 7 miles in width. The areas of investigation, which include these three ground water basins, and the tributary watersheds, have been designated as the "Livermore Valley Unit," "Sunol Valley Unit," and "Southern Alameda Unit," respectively. The location of the Alameda County Area and the three units is shown on Plate 1, entitled "Alameda County Area and Investigative Units."

Drainage Basins

The Livermore Valley Unit is completely surrounded by the Diablo Range, which reaches a maximum elevation of 3,820 feet above sea level in the tributary watershed. The floor of Livermore Valley slopes generally uniformly from an elevation of about 650 feet on the east to about 350 feet on the west. The Sunol Valley Unit lies midway between the Livermore Valley Unit and Southern Alameda Unit, and is also surrounded by mountains. The valley floor is fairly flat, sloping gently from south to north, with an average elevation of about 250 feet above sea level. The Southern Alameda Unit, which lies between the base of the western slope of the Diablo Range and San Francisco Bay, slopes from an elevation of about 100 feet above sea level at its eastern boundary to sea level at the bay.

The relationship of drainage basins of the Alameda County Area is shown on Plate 1. The drainage area tributary to the Livermore Valley totals about 338 square miles. The drainage area tributary to the Sunol Valley embraces about 622 square miles, including the Livermore Valley Unit. The central portion of the Southern Alameda Unit is located downstream from both the Livermore Valley and Sunol Valley Units. Therefore, its tributary drainage area includes the drainage areas of both of the foregoing units in addition to other small areas which drain directly into San Francisco Bay. The total drainage area, including the Southern Alameda Unit, includes about 794 square miles. A portion of this is the San Lorenzo Creek drainage area near Hayward. The extent of the various portions of the drainage basins is shown in the following tabulation.

Unit and basin	Area, in square miles	
Livermore Valley Unit		
Arroyo del Valle, above gaging station near Livermore	149	
Arroyo Mocho, above gaging station near Livermore	38	
Minor streams, above valley floor	151	
Valley floor (to Verona gage)	72	
		410
Sunol Valley Unit		
Alameda Creek, above gaging station near Sunol	33	
San Antonio Creek, above gaging station near Sunol	39	
Calaveras Creek, above gaging station near Sunol	100	
Minor streams, above valley floor	40	
Valley floor (to Niles gage)	11	
		223
Southern Alameda Unit		
San Lorenzo Creek, above gaging station at Hayward	38	
Minor streams, above valley floor	31	
Valley floor (to San Francisco Bay)	92	
		161
TOTAL, Alameda County Area		794

Most of the watershed in the Alameda County Area is drained by Alameda Creek and its tributaries. The Alameda Creek system comprises several streams. Arroyo del Valle and Arroyo Mocho are the principal tributaries in the Livermore Valley Unit and traverse that unit from east to west. These two streams, along with other minor tributaries, drain into Arroyo de la Laguna which heads at the confluence of Alamo Creek and Arroyo Mocho, 1-1/2 miles west of Pleasanton, and flows in a southerly direction for a distance of about 6 miles to the vicinity of Sunol, where it discharges into Alameda Creek. The Sunol Valley Unit is traversed by Alameda Creek, which receives the drainage from Calaveras and San Antonio Creeks upstream from its confluence with Arroyo de la Laguna. Below its confluence with Arroyo de la Laguna, Alameda Creek flows in a westerly direction through Niles Canyon, debouches onto the Southern Alameda Unit at Niles, traverses the Niles Cone area, and discharges into San Francisco Bay. San Lorenzo Creek is the principal stream draining the watershed tributary to the Southern Alameda Unit north of Alameda Creek.

Geology

The Alameda County Area consists of a folded and faulted portion of the Diablo Range on the east and the San Francisco Bay structural depression on the west. The most prominent faults and the axes of major folds in the area commonly trend northwesterly. Several intermontane valleys, chief among which are the Livermore, Sunol, and Castro Valleys, are present within the Diablo Range. Livermore Valley, the largest of these, has been formed in an east-west trending syncline of Plio-Pleistocene sediments.

The rocks in the Alameda County Area range in age from the Franciscan formation of the Jurassic period to Recent alluvial and tidal deposits. The older formations occur mainly in the mountainous areas and underlie younger sediments in the valleys. Only the Quaternary and to some extent the late Tertiary formations have sufficiently high permeability to be classed as water-bearing. The principal water-bearing beds are composed of Quaternary sediments laid down in the inter-montane valleys and along the east side of the San Francisco Bay depression at the western base of the Diablo Range.

Soils

Soils of the Livermore Valley, Sunol Valley, and Southern Alameda Units vary in their physical characteristics and adaptabilities in accordance with differences in parent material, manner of deposition, drainage, and age or degree of development. The soils may be divided into three broad groups: (1) residual soils formed in place from the underlying bedrock, (2) soils derived from old valley fill or terrace deposits, and (3) soils derived from more recent alluvial deposits.

Residual soils that are suitable for irrigated agriculture occur only to a minor extent. These soils are limited in their crop adaptabilities by topographic conditions and generally shallow depths. Irrigated pasture would generally be best suited for some of these lands, although orchard crops would also be suitable in certain locations.

Soils derived from old valley sediments occur mostly along the northern, eastern, and southeastern margins of the Livermore Valley Unit. They occupy a topographic position intermediate between the more recent alluvial soils and the higher-lying residual soils. These soils have, in general, developed distinct, heavy-textured subsoils, which in some areas are hardpan. Where subsoil drainage is adequate, these soils are capable of producing orchards, vineyards, and all types of field crops. Under conditions of adverse subsoil drainage, these soils are best suited to irrigated pasture crops.

The more recent alluvial deposits differ broadly according to the manner of deposition and the nature of the outwash material from which they were derived. Some of the soils have developed under conditions of poor drainage, which in some areas has resulted in an accumulation of soluble salts. Most of these soils, where artifically drained, are suited to a wide variety of crops, particularly alfalfa, pasture, and grain crops. Some alluvial soils are quite gravelly in nature, while others are dominantly fine-textured. All of these soils, however, under proper management are capable of producing a wide variety of crops.

Climate

The climate of the Alameda County Area is generally mild, but varies considerably in temperatures and humidity between its eastern and western boundaries. The climate of the Livermore Valley Unit is typical of central California inland valleys at low elevation, and may be described as semi-arid, with relatively hot; dry summers and cool, moist winters. The climate of the Sunol Valley Unit is similar to that of the Livermore Valley Unit. The climate of the Southern Alameda Unit is influenced markedly by its proximity to San Francisco Bay, which tends to minimize the extremes between winter and summer temperatures.

More than 80 percent of the precipitation on the Alameda County Area occurs during the five months from November through March. The 30-year recorded average growing season at Livermore is 261 days between killing frosts, and the similar 12-year recorded average at Newark is 282 days. Temperatures at Livermore have ranged from the extremes of 19°F to 113°F, while the monthly averages during the period from 1872 to 1953 ranged from 48°F in January to 71°F in August. Temperatures at Newark have ranged from 22°F to 101°F, while the monthly averages during the period from 1924 to 1953 ranged from 48°F in January to 64°F in July.

Present Development

Development of the Alameda County Area began with the founding of Mission San Jose in 1795. Although the mission became one of the most prosperous and populous of all California missions during the early 1800's, development in the Alameda County Area was generally slow. Settlement in Livermore Valley began when Robert Livermore became co-grantee of Rancho las Positas in 1839. The American occupation of California in 1847, and the gold rush in 1849, greatly stimulated settlement in the Alameda County Area.

In 1960 the population of Eden, Washington, Pleasanton, and Murray townships, which roughly comprise the Alameda County Area, was 337,000 as compared with 147,000 in 1950 and 65,200 in 1940. The principal urban centers, Hayward, San Leandro, Fremont, Castro Valley, San Lorenzo, and Livermore, accounted for about 77 percent of the total population of the four townships in 1960, although much of San Leandro lies north of the limits of the Alameda County Area.

Agricultural development in the Alameda County Area dates from the time California belonged to Mexico. Early agriculture, which developed slowly prior to the 1850's, was stimulated by the influx of settlers during and after the gold rush, and for many years was largely restricted to dry-farmed grain, pasture, and truck crops. By 1870 a large part of the area was devoted to barley and wheat. Grape culture became highly profitable in Livermore Valley in the 1880's, and vineyards began to replace grain. Irrigated agriculture developed slowly until the turn of the century, when diminishing profits from grain farming, together with the advent of rural electrification and the development of more satisfactory irrigation pumps, gave impetus to increases in irrigated acreage. This transition from dry farming to irrigated farming has continued gradually to this time.

A survey conducted in 1950 as a part of the Alameda County Investigation showed that irrigated lands in the Livermore Valley, Sunol Valley, and Southern Alameda Units totaled about 30,000 acres, while about 55,000 acres of agricultural lands were not irrigated. Principal irrigated crops, in decreasing order of acreage devoted to each crop, were truck crops, tomatoes, deciduous orchard consisting primarily of apricots, pasture, and sugar beets. The principal dry-farmed crops were grain, pasture, and grapes.

The northern portion of the Southern Alameda Unit is largely developed for industrial, commercial, and urban purposes. It is contiguous to the east bay metropolitan area, which is presently spreading southward at a rate which will, in a few years, preclude all but the most profitable agricultural uses. Availability of a large labor market and an excellent network of railroads and highways enhances industrial development. Industry supported by agricultural production includes plants operated for canning, dehydrating, and freezing of fruits and vegetables. A large beet sugar refinery is located near Alvarado. Solar production and processing of salt on the tidal flats along San Francisco Bay is also an important industry. Several large aggregate plants in the Southern Alameda and Livermore Valley Units produce sand and gravel from the deep and extensive alluvial deposits. Other industries manufacture industrial machinery, steel, and chemicals.

Organization of Report

Results of the Alameda County Investigation are presented in this report in the four ensuing chapters. Chapter II, "Water Supply," contains evaluations of precipitation and surface and subsurface inflow and outflow. It also includes results of investigation and study of the ground water basins, and contains data regarding mineral quality of surface and ground waters. Chapter III, "Water Utilization and Supplemental Requirements," includes data and estimates of land use and water utilization for the present, for the year 1990, and for probable ultimate development, and contains corresponding estimates of supplemental water requirements. It also includes available data on demands for water with respect to times and rates of delivery. Chapter IV, "Plans for Water Development," describes preliminary plans for conservation and utilization of available water supplies to meet supplemental water requirements, including operation and yield studies, design considerations and criteria, and cost estimates. Chapter V, "Conclusions and Recommendation," presents conclusions and recommendations resulting from the investigations and studies.

CHAPTER II. WATER SUPPLY

The Alameda County Area derives its water supply from direct precipitation, tributary surface and subsurface inflow, imports from the South Bay Aqueduct, and imports from the Sierra Nevada by the East Bay Municipal Utility District and the City of San Francisco. The water supply of the area is considered and evaluated in this chapter under the general headings: "Precipitation," "Runoff," "Imported and Exported Water," "Underground Hydrology," "Quality of Water," and "Safe Yield of Presently Developed Water Supply."

The following terms are used as defined in connection with the discussion of water supply in this chapter:

Average--Arithmetical averages relating to periods other than mean periods.

Mean--Arithmetical averages relating to mean periods.

Mean Period--A period chosen to represent conditions of water supply and climate over a long period of years.

Connate Brines--Ocean water that was trapped in ground water basins at the time these basins were inundated by the ocean in past geologic periods.

Juvenile Water--New water of magmatic, volcanic, or cosmic origin added to the terrestrial water supply.

Meteoric Water--Water derived from the atmosphere.

Precipitation Season--The 12-month period from July 1st of a given year through June 30 of the following year.

Water Year--The 12-month period from October 1 of a given year through September 30 of the following year.

In studies for the recently completed Statewide Water Resources Investigation resulting in The California Water Plan, it was determined that the 50 years from 1897-98 through 1946-47 generally constituted the most satisfactory period for estimating mean annual precipitation throughout California. Similarly, the 53-year period from 1894-95 through 1946-47 was selected for determining mean annual runoff. In studies for the Alameda County Investigation, these periods were considered representative of mean conditions of climate and water supply.

The water supply available in the Alameda County Area has been in the past, and is at the present time, greatly affected by operation of surface reservoirs, diversions for export, and imports from distant watersheds. Water is exported by the San Francisco Water Department from Calaveras Reservoir, Sunol filter galleries, and at times from the Pleasanton well field. Water is imported from the Mokelumne and the Tuolumne Rivers in the Sierra Nevada by the East Bay Municipal Utility District and the City of San Francisco, respectively, and recently, the California Department of Water Resources started initial deliveries of water from the Sacramento-San Joaquin Delta through the South Bay Aqueduct.

In the ensuing determinations of water supply available to the Alameda County Area, neither the effects of possible future changes in imports or exports of water, nor the recent South Bay Aqueduct imports, were considered. Dependent upon the influence of these effects, the estimates presented herein may be subject to substantial future modification.

Precipitation

The Alameda County Area lies within the southern fringe of storms which periodically sweep inland from the North Pacific Ocean during winter months. Rainfall resulting from these storms ranges from light to moderate, and comprises a substantial portion of the water supply of the area.

Precipitation Stations and Records

Sixty-two precipitation stations in or adjacent to the Alameda County Area have unbroken records of 10 years duration or longer. These stations are fairly well distributed areally, and their records are sufficient to provide an adequate pattern of precipitation. Most of the records of precipitation were obtained from local agencies and individuals, and have heretofore been unpublished. These unpublished records are on file with the Department of Water Resources. Locations of the precipitation stations are shown on Plate 2, entitled "Lines of Equal Mean Annual Precipitation and Pattern of Natural Runoff." The stations, with their location reference numbers, are listed in Table 1, together with their elevation, periods of record to and including 1960, sources of record, and mean, maximum, and minimum annual precipitation. To facilitate the identification of the stations, numbers have been assigned in accordance with township, range, and section. In this system each section is divided into 40-acre plots which are lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

TABLE 1

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR ALAMEDA COUNTY AREA

Location number and Bulletin No. 1 number	Station	Elevation, in feet	Period of record	Source of record	Mean annual precipitation, in inches	Maximum and minimum annual precipitation: Year	Maximum and minimum annual precipitation: Inches
1N/3W-31Q	Grizzly Peak	1,760	1942-60	USWB	18.99	1957-58 1946-47	47.56 14.38
1N/3W-33J, 2-32	Orinda De Laveaga	410	1908-20	EBMUD	26.30	1910-11 1917-18	41.28 13.74
1N/3W-36Q, 2-33	Lafayette Reservoir	460	1924-60	EBMUD	27.11	1957-58 1958-59	45.93 14.46
1N/2W-25M, 2-35	Walnut Creek (2 miles east southeast)	149	1887-1960	USWB	19.64	1957-58 1923-24	36.21 7.10
1S/4W-1E, 2-29	Berkeley	299	1887-1960	USWB	22.88	1889-90 1923-24	46.00 11.57
1S/3W-15R, 2-36	Wilcox	750	1922-35	EBMUD	29.36	1926-27 1930-31	41.95 18.34
1S/3W-18G, 2-30	Temescal Reservoir	450	1909-34	EBMUD	23.53	1926-27 1919-20	35.75 11.99
1S/3W-25A, 2-45	Valle Vista	550	1924-51	EBMUD	29.71	1940-41 1930-31	43.89 15.87
1S/3W-36R, ----	Upper San Leandro Reservoir	490	1923-60	EBMUD	25.88	1957-58 1930-31	43.11 12.70
1S/2W-17K, ----	St. Mary's College	625	1942-60	USWB	26.53	1957-58 1958-59	46.78 14.83
1S/1E-32E, ----	Alamo Creek	800	1912-60	SFWD	17.65	1957-58 1923-24	30.09 6.98
2S/3W-3E, 2-42	Oakland	440	1874-1958	USWB	22.38	1889-90 1911-12	45.38 11.58
2S/3W-3L, 2-43	Mills College	200	1893-1917	USWB	22.37	1894-95 1897-98	37.19 14.44
2S/3W-11G,	Upper San Leandro Filters (non-recording)	395	1929-60	EBMUD	22.22	1957-58 1958-59	38.61 12.36
2S/3W-26L, 2-44	San Leandro	48	1895-1911	USWB	20.00	1908-09 1897-98	29.92 12.97
2S/3W-29B, 2-011	Oakland W. B. Airpoint	3	1938-60	USWB	17.49	1957-58 1958-59	31.29 10.14
2S/2W-9N, 2-46	Upper San Leandro Reservoir	475	1949-60	EBMUD	25.36	1957-58 1958-59	42.40 14.45
2S/2W-30B, 2-47	Chabot Reservoir	245	1878-1953	EBMUD	21.26	1889-90 1919-20	40.85 10.80
2S/1W-9H, ----	San Ramon Bishop	500	1907-53	Private	20.31	1951-52 1923-24	39.03 7.81
2S/1W-17Q, ----	Old Weidemann Ranch	900	1909-53	Private	24.83	1951-52 1923-24	40.92 10.26
2S/1W-29P, ----	Eden Canyon	800	1937-53	Private	21.67	1957-58 1958-59	38.63 12.68
2S/1W-31D, 2-49	Jensen Ranch	850	1905-60	Private	23.86	1957-58 1923-24	40.16 10.57
2S/1E-3H, ----	Tassajara Creek	750	1912-59	SFWD	16.05	1951-52 1912-13	27.72 6.94
2S/2E-17C, ----	Cayetano Creek	675	1912-60	SFWD	14.80	1951-52 1923-24	25.70 7.06
2S/3E-20K, ----	Altamont	750	1912-59	SFWD	12.99	1951-52 1923-24	21.43 6.11
3S/2W-9J, 2-48	Hayward Union High School	110	1914-60	HUHS	20.42	1940-41 1917-18	37.08 9.56
3S/2W-32A ----	Mt. Eden	35	1940-54	Private	16.29	1940-41 1946-47	29.23 10.50
3S/2W-32C, ----	Mt. Eden (near)	30	1933-54	Private	18.42	1940-41 1933-34	28.15 9.95
3S/1W-2N, 2-004	Dublin (1 mile west)	450	1937-60	Private	18.33	1951-52 1958-59	38.94 12.10
3S/1W-34D, 2-008	Hayward (6 miles east southeast)	925	1940-60	USWB	25.27	1951-52 1958-59	41.78 14.76
3S/1E-10Q, ----	Pleasanton (2 miles northeast)	370	1934-60	Private	15.30	1957-58 1938-39	32.85 9.68
3S/1E-16N, ----	Pleasanton	360	1921-60	SFWD	17.60	1951-52 1923-24	30.35 6.54
3S/1E-17P, ----	Pleasanton Nursery	345	1939-60	USDA	18.41	1957-58 1958-59	32.12 10.04
3S/1E-19R, 2-77	Pleasanton Pumps	320	1911-60	SFWD	20.56	1910-11 1923-24	30.25 7.70
3S/2E-8K, 2-50	Livermore (2 miles east)	480	1871-1960	USWB	13.93	1889-90 1876-77	28.66 6.01
3S/2E-10C, ----	Livermore (east)	470	1920-60	ACFC&WCD	13.63	1951-52 1923-24	24.38 6.49
3S/2E-15Q, ----	Concannon Winery	580	1933-60	Private	12.53	1957-58 1947-48	25.24 6.68
3S/2E-22M, ----	Livermore (2 miles southeast)	640	1943-60	Private	12.80	1957-58 1958-59	22.32 7.59
3S/2E-23D, ----	Wente Winery	775	1940-60	ACFC&WCD	13.07	1957-58 1958-59	22.34 7.18
3S/2E-36K, 2-002	Arroyo Mocho	780	1917-59	SFWD	13.16	1951-52 1923-24	21.67 5.52
4S/2W-5A ----	Baumberg Plant	10	1941-60	Private	16.11	1957-58 1958-59	26.45 8.34
4S/2W-10F, ----	Alvarado	10	1920-60	Private	18.22	1940-41 1958-59	28.66 8.79
4S/2W-20E, 2-57	Alvarado (near)	3	1924-41	USWB	16.15	1940-41 1933-34	25.30 8.20
4S/1W-15P, 2-58	Niles	150	1913-60	SFWD	17.47	1957-58 1923-24	28.04 9.63
4S/1W-21M, ----	Niles (1 mile southwest)	62	1871-1933 1952-60	Private ACFC&WCD	18.22	1889-90 1876-77	35.91 9.34
4S/1W-27A, ----	Niles (2 miles southeast)	75	1935-60	Private	17.72	1957-58 1958-59	28.12 9.74
4S/1W-28C, ----	Niles (1 mile south)	60	1933-60	Private	17.60	1957-58 1958-59	28.85 9.30
4S/1W-29F, ----	Centerville	60	1931-59	Private	17.23	1957-58 1958-59	27.05 8.56
4S/1W-30C, ----	Centerville (near)	50	1940-53	Private	17.24	1940-41 1946-47	26.31 12.54
4S/1E-17B, 2-59	Sunol	260	1898-1960	SFWD	19.90	1914-15 1923-24	31.15 8.27
4S/2E-9H, ----	Patterson Ranch	1,250	1913-60	SFWD	16.88	1951-52 1923-24	27.43 6.31
4S/2E-29D, ----	La Costa Creek	1,000	1917-57	SFWD	20.80	1951-52 1923-24	38.61 8.25
4S/3E-32C, ----	Arroyo del Valle	1,450	1913-54	SFWD	21.25	1937-38 1923-24	37.38 7.58
4S/4E-18P, ----	Crane Ridge	2,430	1918-59	SFWD	16.13	1937-38 1923-24	32.82 6.33
5S/2W-1Q, ----	Newark (0.5 mile south)	10	1914-34	ACFC&WCD	14.26	1921-22 1919-20	18.27 7.32
5S/2W-1Q, ----	Newark	14	1941-60	USWB	14.19	1957-58 1958-59	23.92 7.52
5S/1E-24D, 2-79	Calaveras Reservoir	900	1898-1960	SFWD	20.10	1892-93 1923-24	39.20 7.69
5S/4E-34G, ----	Arroyo Mocho (Santa Clara County)	2,700	1912-59	SFWD	20.32	1937-38 1923-24	31.57 8.80
6S/1W-3K, SC-2*	Alviso	8	1941-53	Private	14.37	1957-58 1958-59	21.44 7.11
6S/4E-36P, 2-81	Gerber Ranch	2,140	1912-60	SFWD	18.44	1937-38 1923-24	31.47 6.85
7S/3E-10E, 2-80	Mount Hamilton	4,209	1881-1960	USWB	27.31	1883-84 1958-59	58.09 9.08
7S/5E-19L ----	Shanti Ashrama	2,300	1912-52	SFWD	21.37	1940-41 1923-24	40.24 7.72

* Published in State Water Resources Board Bulletin No. 7, "Santa Clara Valley Investigation."

ACFC&WCD - Alameda County Flood Control and Water Conservation District
EBMUD - East Bay Municipal Utility District
HUHS - Hayward Union High School
SFWD - San Francisco Water Department
USDA - United States Department of Agriculture
USWB - United States Weather Bureau

As an illustration of the use of this system, precipitation station number 6S/1W-3K would be found in Township 6 South, Range 1 West, and in Section 3. It would be further identified as located in the 40-acre plot lettered K.

Records of 26 of the precipitation stations shown in Table 1 were also utilized in the preparation of State Water Resources Board Bulletin No. 1, "Water Resources of California." The numbers of these stations, as published in Bulletin No. 1, are also included in Table 1.

Precipitation Characteristics

Although the general precipitation pattern in the Alameda County Area is somewhat irregular, as indicated on Plate 2, the patterns of precipitation within each of the Livermore Valley, Sunol Valley, and Southern Alameda Units are quite uniform. For purposes of hydrologic analyses of the ground water basins, certain precipitation stations of long-time record were selected as being representative of precipitation characteristics in those basins. It was concluded that precipitation at Livermore provided a suitable index of general precipitation over the Livermore Valley Unit. The records at Sunol and Niles were similarly considered to be representative of the Sunol Valley and Southern Alameda Units, respectively. Records of precipitation at Livermore and near Niles are available since 1871-72, and at Sunol since 1897-98. Recorded annual precipitation at these stations is presented in Table 2 and is shown graphically on Plate 3, entitled "Mean Monthly and Annual Precipitation at Livermore, at Sunol, and near Niles."

TABLE 2

RECORDED AND ESTIMATED ANNUAL PRECIPITATION AT
LIVERMORE AND SUNOL, AND NEAR NILES

(In Inches)

Year	Livermore	Niles
1871-72	19.06	22.65
72-73	10.69	14.31
73-74	12.26	14.10
74-75	11.67	11.81
75-76	19.99	25.88
1876-77	6.01	9.34
77-78	17.66	24.67
78-79	10.11	14.54
79-80	15.98	17.70
80-81	16.45	20.06
1881-82	11.70	13.55
82-83	13.86	13.80
83-84	22.75	26.25
84-85	12.01	10.70
85-86	16.17	23.35
1886-87	11.17	14.85
87-88	13.13	14.80
88-89	15.81	16.06
89-90	28.66	35.91
90-91	14.16	14.28
1891-92	14.25	16.39
92-93	26.29	23.56
93-94	17.16	21.93
94-95	24.37	27.30
95-96	16.35	19.58
1896-97	17.28	24.22

Year	Livermore	Sunol	Niles
1897-98	9.11	10.51	12.12
98-99	11.76	20.41	15.89
99-00	12.93	22.27	19.37
1900-01	19.82	25.37	24.89
01-02	12.48	19.54	17.47
1902-03	14.25	19.02	17.20
03-04	13.33	22.16	18.63
04-05	15.81	23.29	23.47
05-06	19.32	25.21	23.89
06-07	23.14	29.78	29.16
1907-08	8.91	16.18	14.76
08-09	18.58	25.14	24.54
09-10	14.50	18.53	19.54
10-11	21.28	28.43	27.59
11-12	9.60	15.81	14.76
1912-13	8.23	12.75*	12.76
13-14	17.20	28.20*	23.29
14-15	19.51	31.15	27.34
15-16	20.42	20.58	20.23
16-17	10.58	17.01	14.65
1917-18	8.73	13.70	12.43
18-19	17.99	27.18	22.97
19-20	8.82	13.99	11.29
20-21	13.28	24.99	20.48
21-22	14.05	25.38	20.00
1922-23	13.60	21.52	17.00
23-24	6.03	8.27	9.52
24-25	14.56	24.60	21.58
25-26	11.51	19.74	16.39
26-27	13.32	18.65	18.70
1927-28	12.83	17.61	16.67
28-29	10.09	15.42	14.48
29-30	10.82	14.91	14.58

Year	Livermore	Sunol	Niles
1930-31	9.28	12.11	12.40
31-32	13.20	17.77	18.89
32-33	10.44	15.83	13.70
33-34	9.86	13.80	10.66
34-35	16.41	21.22	19.77
1935-36	14.51	20.44	16.69
36-37	17.31	21.50	19.77
37-38	21.13	25.61	21.80
38-39	9.46	14.87	12.73
39-40	18.68	23.41	22.65
1940-41	18.30	23.13	25.50
41-42	18.07	23.84	21.23
42-43	15.70	19.90	18.29
43-44	11.99	15.20	15.08
44-45	14.32	17.50	17.12
1945-46	10.45	15.57	14.14
46-47	10.82	12.76	12.85
47-48	10.99	15.18	14.72
48-49	11.14	13.79	12.72
49-50	11.81	16.21	14.00
1950-51	19.70	23.96	20.06
51-52	24.19	29.41	26.41
52-53	14.91	17.39	14.41
53-54	11.33	15.02	10.54
54-55	12.44	14.98	12.67
1955-56	20.82	24.37	19.13
56-57	12.03	13.98	12.89
57-58	21.52	28.37	22.76
58-59	7.79	10.46	9.37
59-60	10.81	15.55	16.76
Mean	13.84	19.06	17.13

AVERAGE FOR PERIOD OF RECORD: LIVERMORE: 14.62; SUNOL: 19.53; NILES: 18.08

* - Estimated

Precipitation in the Alameda County Area consists almost entirely of rainfall. Snow falls only occasionally and melts very quickly. As shown on Plate 2, precipitation increases from southwest to northeast toward the Diablo Range in the Southern Alameda Unit, is practically uniform in the Sunol Valley Unit, and decreases uniformly from west to east across the Livermore Valley Unit. Mean annual precipitation ranges from about 14 to 22 inches in the Southern Alameda Unit, is uniform at about 20 inches in the Sunol Valley Unit, and ranges from about 13 to 22 inches in the Livermore Valley Unit. The average mean annual precipitation over the entire areas of the foregoing units is about 18 inches, 20 inches, and 15 inches, respectively.

As indicated by Table 2 and Plate 3, precipitation in the Alameda County Area varies widely from year to year, ranging from less than 40 percent to more than 200 percent of the annual mean. Maximum recorded annual precipitation at both Livermore and Niles occurred in 1889-90, when 28.66 inches and 35.91 inches of rainfall were recorded, respectively. Minimum seasonal precipitation at these stations occurred in 1876-77, with only 6.01 inches and 9.34 inches recorded, respectively.

More than 80 percent of the mean annual precipitation in the Alameda County Area normally falls during the five months from November through March. The mean monthly distribution of precipitation at Livermore, Sunol, and Niles is presented in Table 3.

TABLE 3

MEAN MONTHLY DISTRIBUTION OF PRECIPITATION AT LIVERMORE AND SUNOL, AND NEAR NILES

Month	Livermore		Sunol		Near Niles	
	Inches	Percent of annual total	Inches	Percent of annual total	Inches	Percent of annual total
July	0.01	0.1	0.01	0.1	0.01	0.1
August	0.01	0.1	0.02	0.1	0.02	0.1
September	0.24	1.7	0.29	1.5	0.27	1.6
October	0.56	4.0	0.79	4.1	0.72	4.2
November	1.32	9.6	2.08	10.9	1.69	9.8
December	2.64	19.1	3.35	17.5	3.16	18.5
January	3.07	22.2	3.92	20.5	3.70	21.6
February	2.52	18.2	3.64	19.0	3.11	18.2
March	1.86	13.4	2.85	14.9	2.44	14.2
April	1.04	7.5	1.36	7.1	1.17	6.8
May	0.47	3.4	0.67	3.5	0.68	4.0
June	0.10	0.7	0.15	0.8	0.15	0.9
TOTALS	13.84	100.0	19.13	100.0	17.12	100.0

Note: Estimates for periods of missing record are not used in computing means.

Quantity of Precipitation

The mean annual precipitation at 92 stations in the Alameda County Area, including 30 stations with records of less than 10 years, was estimated and plotted on a map. Lines of equal mean annual precipitation, or isohyets, were then drawn.

These are depicted on Plate 2. The total quantity of precipitation, in acre-feet, was estimated by multiplying the area between these isohyets, in acres, by the average depths of precipitation between the isohyets, in feet.

Yearly quantities of precipitation during the investigational period were estimated by adjusting the foregoing estimates for the mean period on the basis of recorded precipitation at Livermore and Niles for the Livermore Valley and Southern Alameda Units, respectively. The results of the estimates are presented in Table 4 which also shows the precipitation index for each of the years of the investigation. The term "precipitation index" refers to the ratio of the amount of precipitation during a given year to the mean annual amount, expressed as a precentage.

TABLE 4

ESTIMATED YEARLY TOTAL QUANTITY OF PRECIPITATION
IN UNITS OF ALAMEDA COUNTY AREA

(In acre-feet)

Unit and zone	Year				
	1948-49	1949-50	1950-51	1951-52	Mean
Livermore Valley Unit					
Free ground water zone	44,400	45,400	76,300	94,100	54,100
Confined ground water zone	4,800	5,000	8,300	10,300	5,900
TOTALS	49,200	50,400	84,600	104,400	60,000
Precipitation Index	82	84	141	174	100
Southern Alameda Unit					
Free ground water zone	19,800	21,800	31,400	40,700	28,300
Confined ground water zone	40,200	44,200	63,700	82,700	57,400
TOTALS	60,000	66,000	95,100	123,400	85,700
Precipitation Index	70	77	111	144	100

Certain of the estimates presented in Table 4 were utilized in hydrologic analyses of the Livermore Valley and Southern Alameda Units. These are presented in ensuing sections of this bulletin. Such a hydrologic analysis was not attempted in the Sunol Valley Unit because of the control of the ground water basin of that unit by the operation of Sunol Dam and filter galleries by the San Francisco Water Department. For this reason, estimates of precipitation in the Sunol Valley Unit were not included in Table 4.

Runoff

Runoff from the low to moderately productive watersheds of the Diablo Range constitutes a substantial source of water supply available to the hydrologic units of the Alameda County Area. Alameda Creek is the principal tributary stream, heading near Mt. Hamilton and flowing in a northwesterly direction for about 20 miles, and intercepting runoff of Calaveras and San Antonio Creeks before reaching Sunol Valley. At its confluence with Arroyo de la Laguna near Sunol, Alameda Creek swings west and flows through Niles Canyon and across the Southern Alameda Unit, where it discharges into San Francisco Bay. Arroyo de la Laguna drains the Livermore Valley Unit. Its principal tributary is Arroyo del Valle, which traverses the Livermore Valley Unit from east to west and discharges into Arroyo de la Laguna near Pleasanton. Arroyo Mocho and Alamo Creek are also tributary to Arroyo de la Laguna.

The San Francisco Water Department operates Calaveras Reservoir on Calaveras Creek, a diversion dam on Alameda Creek, and a diversion tunnel between Alameda Creek and Calaveras Reservoir for the development of water for export to its service area. Although the watershed tributary to the Livermore Valley Unit is not yet developed by significant surface storage, the San Francisco Water Department has until recently exercised pumping rights for the extraction of ground water from the Pleasanton gravels for purposes of export. However, under a recent agreement with the City of Pleasanton the San Francisco Water Department has agreed to not export water from its Pleasanton well field. The ground water basin in the Livermore Valley Unit has also been developed by agricultural interests, the Cities of Pleasanton and Livermore, and by the U. S. Government at Camp Parks.

Stream Gaging Stations and Records

To supplement available hydrologic data, 15 stream gaging stations were reactivated or installed in the Livermore Valley and Southern Alameda Units during the course of the investigation. Stations previously operated by the Spring Valley Water Company on Arroyo del Valle near Livermore, Arroyo Mocho near Livermore, and San Antonio Creek were reactivated. Stations on Arroyo las Positas near Livermore, Tassajara Creek near Pleasanton, and Alamo Creek near Pleasanton were constructed in the same vicinity as stations previously operated by the Spring Valley Water Company. The station on Arroyo de la Laguna near Pleasanton was relocated at State Route 21 bridge, which is 1.5 miles upstream from the station previously operated by the Spring Valley Water Company. The bridge location was used because it afforded better control and accessibility.

New stations in the Southern Alameda Unit were installed on Dry Creek at State Route 9 and at Nursery Road, on Alameda Creek near Alvarado and at Shinn Pit, on Patterson Slough at State Route 17, on San Lorenzo Creek at Hayward Union High School and at Lorenzo Avenue, and on San Leandro Creek at Freeway Overpass and 98th Avenue. However, entirely satisfactory records were obtained only on Dry Creek at State Route 9 and on Patterson Slough at State Route 17. Flood conditions, which caused equipment washouts and other field difficulties, resulted in generally unsatisfactory records on Alameda Creek, Dry Creek at Nursery Road, San Lorenzo Creek, and San Leandro Creek.

The flow in Alameda Creek below Patterson Slough is regulated by a dike which diverts all but flood flows through Patterson Slough. Discharges in the Old Alameda Creek channel were computed from water stages in Patterson Slough at State Route 17. Runoff of these channels comprises most of the outflow from the Southern Alameda Unit. Because of the short duration of the records it was necessary to estimate the outflow for most years by correlation with recorded runoff of Alameda Creek near Niles. Likewise, records of runoff of certain of the smaller tributary streams were nonexistent or confined principally to measurements made during the investigation, thus necessitating estimates based on correlation with streams having recorded runoff.

Table 5 lists those stream gaging stations pertinent to the hydrography of the Alameda County Area, together with their map reference numbers, drainage areas above station (where significant), and periods and sources of records. These stations are shown also on Plate 2. The map reference numbers for all except the last three stations listed correspond to those used in State Water Resources Board Bulletin No. 1. New map reference numbers were assigned to the last three stations listed. Most of the runoff records listed in Table 5 have been published by the Geological Survey of the United States Department of the Interior in its Water Supply papers. With the exception of the cited unsatisfactory records, those records which have not been previously published are included as Appendix B to this bulletin.

TABLE 5

STREAM GAGING STATIONS IN
ALAMEDA COUNTY AREA

Map reference number	Stream	Station	Drainage area, in square miles	Period of record	Source of record
2-20	Alamo Creek	near Dublin	40.4	1914-20 1920-24 1948-50	SFWD, and USGS SFWD DWR
2-21	Tassajara Creek	near Pleasanton	27.9	1914-19 1919-22 1922-29 1929-31 1948-50	SFWD, and USGS SFWD SFWD, and USGS SFWD DWR
2-22	Arroyo las Positas	near Livermore	69.5	1912-29 1929-31 1948-50	SFWD, and USGS SFWD DWR
2-23	Arroyo de la Laguna	near Pleasanton	412*	1912-29	SFWD, and USGS
		at Verona	410	1948-51 1951-60	DWR ACFC&WCD
2-24	San Antonio Creek	near Sunol	39.7	1912-29 1929-34 1949-51 1951-54 1960	SFWD, and USGS SFWD DWR ACFC&WCD USGS
2-25	Arroyo Mocho	near Livermore	38.3	1912-29 1929-31 1948-50 1951-55	SFWD, and USGS SFWD DWR ACFC&WCD
2-26	Arroyo del Valle	near Livermore	149	1904-08 1912-29 1929-31 1941-48 1948-50 1951-57 1957-60	SFWD SFWD, and USGS SFWD SFWD DWR ACFC&WCD USGS
2-27	Calaveras Creek	near Sunol	100	1898-1908 1910-29 1929-54	SFWD SFWD, and USGS SFWD
2-28	Alameda Creek	near Sunol	37.9	1911-29 1929-31	SFWD, and USGS SFWD
2-29	Alameda Creek	at Sunol	622	1900-29 1929-54	SFWD, and USGS SFWD
2-30	Alameda Creek	near Niles	633	1916-60	USGS
2-31	Alameda Creek	at Niles Dam	631	1889-91 1891-1900	SFWD SFWD, and USGS
2-31a	Spring Valley Company Aqueduct	near Niles	----	1900-03 1903-29	SFWD SFWD, and USGS
2-32	Dry Creek	near Decoto	9.4	1916-19	USGS
2-33	Alameda Creek	near Decoto	**	1916-19	USGS
2-34	Crandall Slough	near Centerville	**	1916-19	USGS
2-35	San Lorenzo Creek	at Hayward	38	1940-41 1946-60	USGS USGS
2-36	Laguna Creek	at Irvington	10.8	1916-19	USGS
AC-1	Patterson Slough	at State Route 17	**	1950-51 1951-58 1958-60	DWR ACFC&WCD USGS
AC-2	Alameda Creek	near Union City	**	1950-51 1958-60	DWR USGS
AC-3	Dry Creek	at State Route 9	9.4	1949-51 1951-60	DWR ACFC&WCD and USGS
	Arroyo del Valle	near Pleasanton	17.1	1958-60	USGS
	Cull Creek		6.3	1958-60	ACFC&WCD
	San Lorenzo Creek		19.6	1958-60	ACFC&WCD

* Station relocated in 1918. Prior to 1918 the drainage area was 401 square miles.
** Not determined, since stations are on delta branches of Alameda Creek.

ACFC&WCD - Alameda County Flood Control and Water Conservation District
DWR - Division of Water Resources
EBMUD - East Bay Municipal Utility District
SFWD - San Francisco Water Department
USGS - United States Geological Survey

Runoff Characteristics

Because runoff in the Alameda County Area is derived entirely from rainfall, it exhibits monthly and yearly variations similar to the rainfall variations. Discharge of tributary streams increases greatly within a few hours following major storms. Runoff characteristics in the area are exemplified by recorded and estimated annual runoff of Alameda Creek near Niles and of Arroyo del Valle near Livermore.

An excellent continuous record of flow of Alameda Creek near Niles is available since October 1916, when a stream gaging station was established by the State Water Commission, 1.2 miles above Niles. Records have been published by the United States Geological Survey since that date. Prior to that date runoff was measured at two other locations on Alameda Creek below its confluence with Arroyo de la Laguna. The first record of runoff at Niles Dam, about one-quarter of a mile below Stonybrook Canyon, dates back to December of 1889, and continues through September 30, 1900. This record was kept by the Spring Valley Water Company and was a subject of much argument between parties interested in Alameda Creek. The flow figures for the period January 1, 1891, to September 30, 1900, as published in United States Geological Survey Water Supply Paper 591, were finally accepted as being correct. The Spring Valley Water Company maintained a station at Sunol Dam, one mile west of Sunol, from October 4, 1900, to September 30, 1928, and these records are published in the United States Geological Survey Water Supply Papers as "Alameda Creek at Sunol."

The flow of Alameda Creek is impaired by operation of Calaveras Reservoir, the Sunol filter galleries, the Pleasanton well field, and consumptive use on land in the Sunol Valley and Livermore Valley Units. An estimate of the natural runoff of Alameda Creek at Niles, as it would be if unaltered by upstream diversion, storage, export, or consumptive use of water caused by development, is published in State Water Resources Board Bulletin No. 1. This estimate, together with recorded annual runoff of Alameda Creek at Niles, is presented in Table 6. The estimate of natural flow is illustrated graphically in Figure 1, entitled "Runoff Characteristics."

TABLE 6

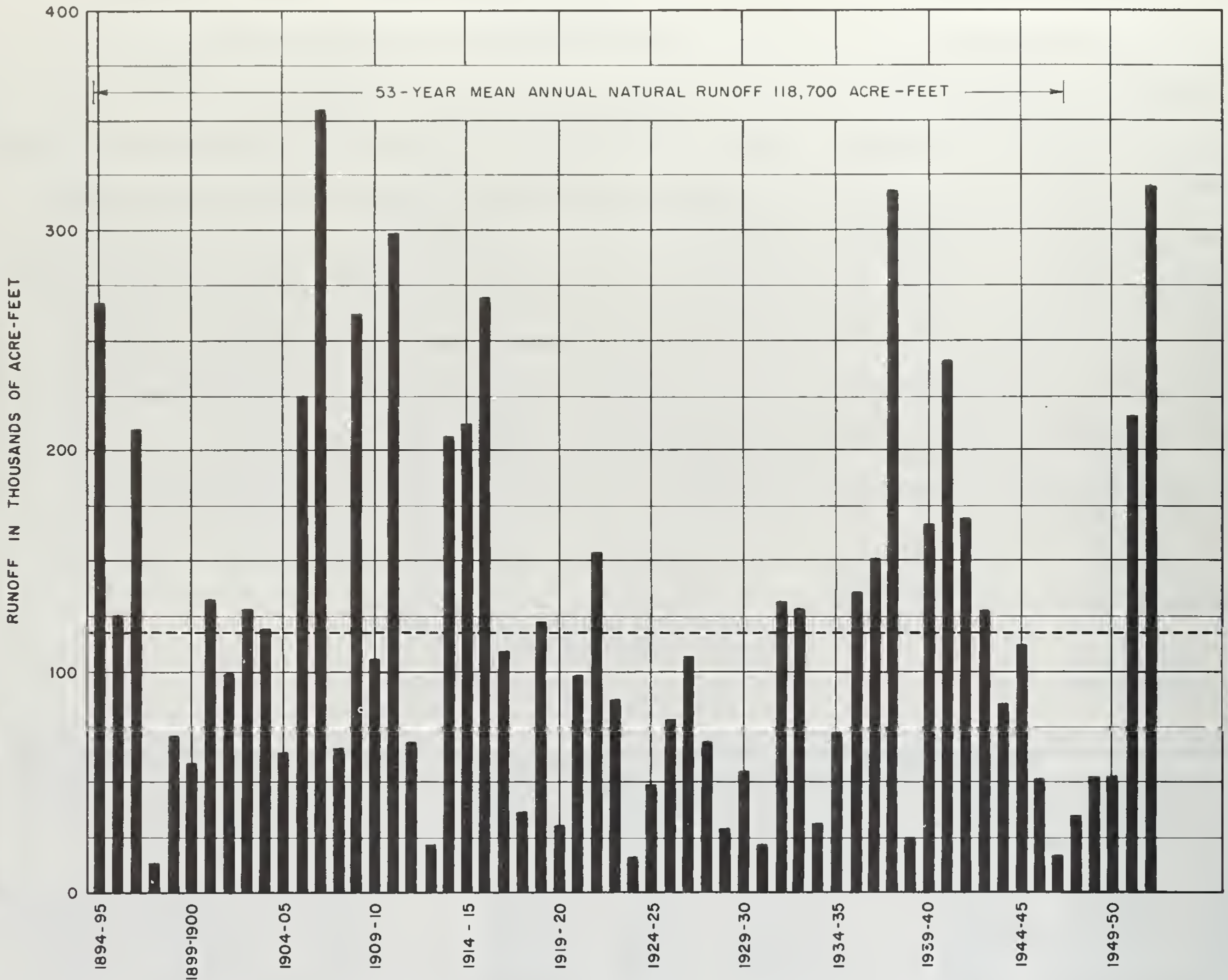
RECORDED AND ESTIMATED NATURAL ANNUAL RUNOFF
OF ALAMEDA CREEK NEAR NILES

(In acre-feet)

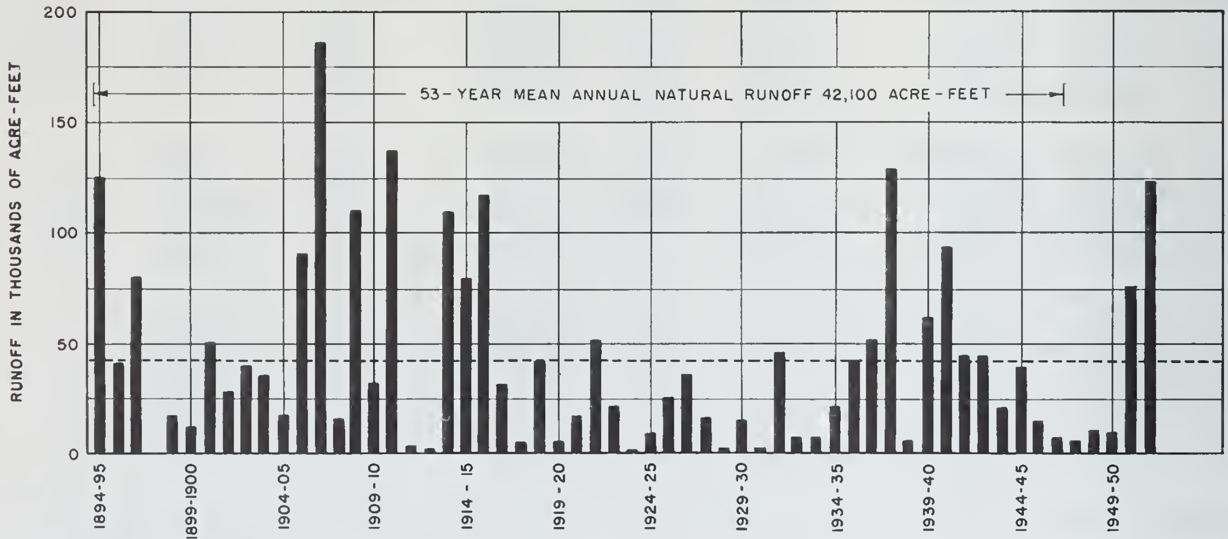
Year	Recorded runoff	Estimated natural runoff	Year	Recorded runoff	Estimated natural runoff	Year	Recorded runoff	Estimated natural runoff
1894-95	263,000	268,000	1916-17	86,000	109,000	1938-39	15,200	24,400
95-96	118,000	125,000	17-18	12,600	36,600	39-40	92,600	167,000
96-97	204,000	210,000	18-19	107,000	123,000	40-41	200,000	242,000
97-98	7,020	13,600	19-20	8,200	31,100	41-42	128,000	169,000
98-99	64,100	71,000	20-21	72,500	98,800	42-43	79,500	127,000
1899-1900	51,700	59,200	1921-22	131,000	155,000	1943-44	35,000	85,700
00-01	119,000	133,000	22-23	58,000	87,900	44-45	44,100	112,000
01-02	83,800	99,100	23-24	2,100	16,600	45-46	15,700	51,900
02-03	110,000	128,000	24-25	18,700	49,200	46-47	2,100	17,300
03-04	98,300	119,000	25-26	31,000	79,000	47-48	900	34,900
1904-05	45,400	63,600	1926-27	48,300	108,000	1948-49	5,600	53,300
05-06	203,000	225,000	27-28	30,100	69,000	49-50	8,700	52,900
06-07	324,000	355,000	28-29	5,200	28,700	50-51	112,900	216,300
07-08	46,500	65,900	29-30	19,200	56,500	51-52	285,000	319,900
08-09	239,000	263,000	30-31	1,200	22,700	52-53	24,760	
1909-10	84,200	106,000	1931-32	57,400	132,000	1953-54	4,250	
10-11	272,000	299,000	32-33	7,000	29,300	54-55	5,900	
11-12	16,500	34,700	33-34	7,900	32,200	55-56	200,000	
12-13	6,550	21,800	34-35	30,500	72,700	56-57	7,880	
13-14	179,000	207,000	35-36	77,150	136,000	57-58	245,700	
1914-15	182,000	213,000	1936-37	100,100	150,000	1958-59	14,660	
15-16	233,000	270,000	37-38	286,000	319,000	59-60	11,940	

MEAN ANNUAL NATURAL RUNOFF FOR 53 YEAR MEAN PERIOD, 1894-95 THROUGH 1946-47 - 118,700 ACRE-FEET

About 65 percent of the runoff tributary to the Livermore Valley Unit occurs in Arroyo del Valle, and is characteristic of runoff to that unit. The



ESTIMATED ANNUAL NATURAL RUNOFF OF ALAMEDA CREEK NEAR NILES



ESTIMATED ANNUAL NATURAL RUNOFF TRIBUTARY TO LIVERMORE VALLEY UNIT

Figure 1. RUNOFF CHARACTERISTICS

estimated and recorded runoff of Arroyo del Valle is shown in Table 7. The estimated natural runoff of all streams tributary to the Livermore Valley Unit is shown graphically in Figure 1.

TABLE 7

RECORDED AND ESTIMATED NATURAL ANNUAL RUNOFF
OF ARROYO DEL VALLE NEAR LIVERMORE

(In acre-feet)

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
1894-95	66,500*	1911-12	2,520	1928-29	1,880	1945-46	9,000
95-96	26,000*	12-13	1,700	29-30	11,400	46-47	4,300
96-97	50,000*	13-14	85,400	30-31	1,000	47-48	
97-98	0*	14-15	47,000	31-32	30,000*	48-49	8,000
98-99	12,200*	15-16	63,300	32-33	4,500*	49-50	7,200
1899-1900	9,000*	1916-17	23,400	1933-34	4,500*	1950-51	40,800
00-01	28,800*	17-18	3,170	34-35	12,000*	51-52	57,900
01-02	19,500*	18-19	23,100	35-36	29,000*	52-53	na
02-03	27,500*	19-20	3,880	36-37	33,000*	53-54	na
03-04	25,000*	20-21	12,200	37-38	82,000*	54-55	na
1904-05	10,100*	1921-22	34,900	1938-39	2,000*	1955-56	na
05-06	54,200*	22-23	15,000	39-40	37,500*	56-57	na
06-07	91,700*	23-24	0	40-41	59,000*	57-58	na
07-08	10,700	24-25	4,100	41-42	19,400	58-59	15,630
08-09	65,000*	25-26	19,700	42-43	28,000*	59-60	7,480
1909-10	21,300*	1926-27	26,500	1943-44	13,200		
10-11	75,700*	27-28	11,600	44-45	28,300		

MEAN ANNUAL NATURAL RUNOFF FOR 53 YEAR PERIOD, 1894-95 THROUGH 1946-47 - 26,000 ACRE-FEET

* Estimated
na Record not available

Discharge of streams of the Alameda County Area varies between wide limits from year to year and within each year. This is indicated by the flow of Alameda Creek at Niles Dam for the period of record, where the maximum recorded annual runoff occurred in 1892-93 and amounted to 360,000 acre-feet. The minimum recorded annual runoff occurred in 1947-48 and was less than 900 acre-feet. The estimated minimum annual natural runoff, 13,600 acre-feet, occurred in 1897-98. The maximum recorded instantaneous discharge near Niles was 21,000 second-feet on December 23, 1955.

Quantity of Runoff

Available records of stream flow, including those obtained from measurements made in connection with the investigation, were sufficient to permit determination of surface inflow to and outflow from the Livermore Valley and Southern Alameda Units during the period of investigation.

Surface inflow to the Livermore Valley Unit was measured directly on Arroyo del Valle, Arroyo Mocho, and Arroyo las Positas near Livermore, and on Alamo and Tassajara Creeks near Pleasanton. Surface inflow from 46 square miles of tributary watershed was not susceptible of measurement at the five foregoing stream gaging stations. The amount of such surface inflow was estimated from the observed precipitation-runoff relationship in the generally similar watershed tributary to Chabot Reservoir on San Leandro Creek. In other instances, records of flow were nonexistent. The runoff of those streams was correlated with the full natural flow of Alameda Creek near Niles, as reported in State Water Resources Board Bulletin No. 1. Surface outflow from the Livermore Valley Unit is concentrated in Arroyo de la Laguna and is susceptible of direct measurement at its exit from that unit near Pleasanton.

Measured and estimated annual surface inflow to and outflow from the Livermore Valley Unit for the seasons 1948-49 through 1951-52 are presented in Table 8.

TABLE 8

MEASURED AND ESTIMATED ANNUAL SURFACE INFLOW TO AND OUTFLOW FROM LIVERMORE VALLEY UNIT

(In acre-feet)

Stream	1948-49	1949-50	1950-51	1951-52	Average for 4-year period, 1948-49 through 1951-52	Mean
Inflow						
Arroyo del Valle	8,000	7,200	40,800	57,900	28,500	26,000
Arroyo Mocho	1,100	700	6,600	10,700	4,800	4,000
Arroyo las Positas	0	0	3,300	9,600	3,200	2,000
Alamo Creek	200	400	10,800	16,400	7,000	4,200
Tassajara Creek	100	0	4,300	9,600	3,500	2,300
Unmeasured inflow*	600	800	10,500	19,800	7,900	3,600
TOTALS	10,000	9,100	76,300	124,000	54,900	42,100
Outflow						
Arroyo de la Laguna	3,200	4,400	81,000	95,400	46,000	39,100

* Includes subsurface inflow.

Surface outflow from the Southern Alameda Unit was measured in Patterson Slough at State Route 17 and in Old Alameda Creek channel near Alvarado for the water years 1950-51 and 1951-52. Runoff in these channels was correlated with that of

Alameda Creek near Niles for the years 1948-49 and 1949-50. The remaining surface outflow from the Southern Alameda Unit is carried by San Lorenzo Creek, and was estimated by correlation with measured runoff of San Lorenzo Creek near Hayward.

Measured and estimated annual surface inflow to and outflow from the Southern Alameda Unit during the period 1948-49 through 1951-52 are presented in Table 9. It will be noted in Table 9 that the estimated inflow shown for Alameda Creek during the mean period is based upon present impairments. This estimate represents the inflow that would have been measured in Alameda Creek, had present upstream impairments been in effect during the mean period. Since the completion of Calaveras Reservoir in 1925, the last development on Alameda Creek, the historical inflow in that stream has reflected its present degree of impairment. However, prior to that date it was necessary to adjust the historical inflow to take into account the effect of subsequent upstream developments.

TABLE 9

MEASURED AND ESTIMATED ANNUAL SURFACE INFLOW TO AND OUTFLOW FROM SOUTHERN ALAMEDA UNIT

(In acre-feet)

Stream	1948-49	1949-50	1950-51	1951-52	Average for 4-year period 1948-49 through 1951-52	Mean
Inflow						
Alameda Creek 1/	5,600	8,700	112,900	285,000	103,000	78,300
San Lorenzo Creek	3,800	6,500	22,300	28,900	15,400	11,300
Dry Creek	500	1,100	3,800	10,500	4,000	1,800
Unmeasured inflow 1/	1,600	2,500	8,900	19,100	8,000	6,400
TOTALS 2/	11,500	18,800	147,900	343,500	130,400	97,800
Outflow						
Alameda Creek 3/	2,700	3,700	99,900	261,800	92,000	68,600
San Lorenzo Creek	4,800	10,700	31,700	40,300	21,900	13,800
TOTALS	7,500	14,400	131,600	302,100	113,900	82,400

1/ Includes subsurface inflow
2/ Based upon present impairments
3/ Includes Old Alameda Creek channel and Patterson Slough

Surface inflow to the Southern Alameda Unit was measured at the Niles station on Alameda Creek, and at Hayward on San Lorenzo Creek, for the water years 1948-49 through 1951-52. The flow of Dry Creek was measured at State Route 9 from 1949-50 through 1951-52. Inflow at this station for the year 1948-49 was estimated by precipitation-runoff correlation. Unmeasured runoff from minor drainage areas tributary to the Southern Alameda Unit was estimated by correlation with the observed precipitation-runoff relationship on the Chabot Reservoir watershed.

Imported and Exported Water

The import and export of water has played a highly significant role in the history of development of the water resources of the Alameda County Area. Exports from the area date back to about 1893 when the Oakland Water Company, predecessor to the East Bay Municipal Utility District, supplied a portion of the City of Oakland and the Town of Alvarado from a pumping plant drawing on artesian wells near Alvarado. Pumping from the Alvarado wells was discontinued in 1930.

The most significant exports from the Alameda County Area began about 1898 when the Spring Valley Water Company, predecessor to the San Francisco Water Department, drilled a series of wells into the extensive gravel beds in the western portion of the Livermore Valley Unit near Pleasanton. Water from these wells, which were originally artesian, was conveyed by pipeline to the Sunol filter galleries, where it was collected, along with water from Alameda and San Antonio Creeks, and discharged into a gravity conduit through Niles Canyon to Niles Reservoir. From Niles Reservoir the water was released into a conduit crossing beneath San Francisco Bay. A pumping plant located near the western shore of the bay boosted the water into Crystal Springs Reservoir, whence it served the City of San Francisco by a gravity distribution system. Exports from the Pleasanton well field have varied over wide limits from season to season, ranging from zero to nearly 14,000 acre-feet per season, and averaging about 4,200 acre-feet annually from 1911 to 1952. The Pleasanton well field was originally a very important part of the water supply of the City of San Francisco, but as new and larger sources were added to the water supply system serving the city, the well field was reduced to a role of successively lesser significance. Through an agreement with the City of Pleasanton, the San Francisco Water Department has agreed to not export water from the Pleasanton well field but does contemplate serving water to land owned by the city and to the Castlewood Country Club.

The only appreciable pumping from the Pleasanton well field since the completion of the Hetch Hetchy Aqueduct in 1934 occurred during the 15-month period from February 1948, to May 1949, just prior to the completion of the second barrel of the aqueduct, then under construction. During this period the San Francisco Water Department pumped nearly 14,000 acre-feet of water for export to the peninsulla. Recorded annual exports of water from the Pleasanton well field, which constitutes the only historical export from the Livermore Valley Unit, are presented in Table 10. There are no known imports of water to that unit prior to 1961.

TABLE 10

RECORDED ANNUAL EXPORTS OF WATER FROM
PLEASANTON WELL FIELD IN LIVERMORE VALLEY UNIT

(In acre-feet)

Water year	Export	Water year	Export	Water year	Export
1911-12	6,700	1928-29	4,700	1945-46	0
12-13	8,200	29-30	10,100	46-47	0
13-14	6,400			47-48	7,800
14-15	8,000	1930-31	11,200	48-49	6,200
		31-32	8,100	49-50	0
1915-16	7,300	32-33	1,000		
16-17	5,600	33-34	8,300	1950-51	0
17-18	9,400	34-35	0	51-52	0
18-19	6,600			52-53	0
19-20	8,200	1935-36	11,200	53-54	0
		36-37	8,100	54-55	0
1920-21	5,500	37-38	1,000		
21-22	1,600	38-39	8,300	1955-56	0
22-23	1,300	39-40	0	56-57	0
23-24	6,300			57-58	0
24-25	12,800	1940-41	0	58-59	0
		41-42	0	59-60	0
1925-26	7,200	42-43	0		
26-27	5,900	43-44	0		
27-28	6,600	44-45	0		

The last major development for export of water from the Alameda County Area involved the construction of Calaveras Dam and Reservoir on Calaveras Creek, about 9 miles south of Sunol, and the diversion dam and tunnel on upper Alameda Creek which diverts water into Calaveras Reservoir. This project began operation in 1924. Water from Calaveras Reservoir was originally released into the natural stream channel where it was collected at the Sunol filter galleries, along with water from the Pleasanton well field, and exported to Crystal Springs Reservoir. However, after completion of the Hetch Hetchy Aqueduct in 1934, a pipeline was installed from Calaveras Dam to the Alameda Creek crossing of the aqueduct, allowing direct gravity diversion from Calaveras Reservoir to Crystal Springs Reservoir. Although Calaveras Reservoir has been reduced in significance as a principal source of water supply for the San Francisco Water Department since the completion of the second barrel of the Hetch Hetchy Aqueduct, the use of that reservoir has not been decreased. Diversions during the several seasons immediately preceding the field investigation and during the field investigation averaged about 25,000 acre-feet per season.

The earliest major import of water to the Alameda County Area began in 1930 with completion of the Mokelumne Aqueduct by the East Bay Municipal Utility District. Prior to that time the district served the water in the area from the Robert's Landing wells and the aforementioned Alvarado wells, in addition to its own system of surface reservoirs, including Chabot and Upper San Leandro Reservoirs on San Leandro Creek. The Robert's Landing and Alvarado wells were abandoned soon after water service from the Mokelumne Aqueduct was secured. As shown on Plate 4, entitled "Water Agencies and Developments," the Alameda County Area extends only into the southern fringe of the East Bay Municipal Utility District service area. Therefore, the seasonal imports to the Alameda County Area from the water supply system of that district, as presented in Table 11, represent only a small part of the total imports to the East Bay area from that system. It is significant, however, to note the rapid recent increase in delivery of water by the district to the Southern Alameda Unit. Imports from the district's system will become an increasingly important source of water to the Southern Alameda Unit for a twofold reason: (1) an increase in population density in the areas presently served, and (2) the expansion of the service area of the East Bay Municipal Utility District.

The Hetch Hetchy Aqueduct traverses the Alameda County Area and, as mentioned in a preceding paragraph, it is used to convey water from the Alameda Creek system which can be directly released from Calaveras Reservoir and pumped from Niles Reservoir. There are also provisions for release of water from the Hetch Hetchy Aqueduct to users in the Niles Cone area. The Alameda County Water District purchases small amounts of water from the San Francisco Water Department at the aqueduct. The City of Hayward began obtaining water from the aqueduct in 1950, and has increased its use of this imported water from 1,000 acre-feet in 1950 to 3,500 acre-feet in 1953 to 7,950 acre-feet in 1961.

Historical imports of water to the Southern Alameda Unit, and exports from the tributary watershed, from 1930 to 1953, are presented in Table 11.

TABLE 11

RECORDED AND ESTIMATED ANNUAL IMPORTS
OF WATER TO SOUTHERN ALAMEDA UNIT,
AND EXPORTS FROM TRIBUTARY WATERSHED

(In acre-feet)

Water year	Imports		Exports
	East Bay Municipal Utility District water supply system1/	Hetch Hetchy Aqueduct	Calaveras Reservoir and Sunol filter galleries
1930-31	300		20,700
31-32	300		26,300
32-33	300		50,500
33-34	300		26,100
34-35	300		9,200
1935-36	300		16,600
36-37	300		25,300
37-38	300		35,000
38-39	400	10	48,800
39-40	500	20	15,000
1940-41	600	20	35,000
41-42	600	40	43,500
42-43	800	40	51,800
43-44	1,100	0	50,900
44-45	1,500	10	41,800
1945-46	2,100	20	56,100
46-47	2,600	280	40,900
47-48	3,100	310	32,600 2/
48-49	3,900	150	18,800 2/
49-50	4,400	1,200	26,800 2/
1950-51	5,100	2,000	16,100 2/
51-52	6,000	2,300	21,000 2/
52-53	7,000	2,800	12,900 2/

1/ Includes minor quantity of local yield of Chabot and Upper San Leandro Reservoirs.
2/ Calaveras Reservoir releases only.

Ground Water Hydrology

There are two principal ground water producing areas in the Alameda County Area. They are Livermore Valley and the Bay Plain, located along the eastern shore of San Francisco Bay. Underlain by water-bearing materials of considerable storage capacity, they produce ground water supplies that serve nearly all the irrigated lands in the area, with the exception of those lands in the Sunol Valley served by the San Francisco Water Department. Other than the imports from the East Bay Municipal Utility District and from the Hetch Hetchy Aqueduct, ground water resources also provide the urban and industrial requirements in the Alameda County Area. Infiltration and percolation of stream flow is the most important source of ground water replenishment in the area. Infiltration and percolation of rainfall and the unconsumed portion of applied irrigation water, as well as subsurface movement of ground water from upland areas bordering the valleys and from beneath San Francisco Bay, constitute secondary sources of replenishment.

The term "free ground water," as used in this bulletin, refers to a body of ground water not overlain by impervious materials, and moving under control of the water table slope. "Unconfined ground water" refers to a body of ground water that is overlain by material sufficiently impervious to sever free hydraulic connection with overlying water; however, an air gap exists between the water surface and overlying impervious layer; and the water is not under pressure, but moves under control of the water table slope. "Confined ground water" refers to ground water that is overlain by an impervious layer that severs hydraulic connection with overlying water; however, the aquifer is completely saturated, and the water is under pressure caused by difference in head between intake and discharge areas of the confined water body. A free ground water area usually serves as a forebay or intake to confined and unconfined water bodies and constitutes their source of replenishment. Free and unconfined ground water areas of a ground water basin provide regulatory storage to smooth out fluctuations in available water supplies, and changes in ground water storage are indicated by changes in ground water levels in these areas.

Data and information collected during the Alameda County Investigation indicate that irrigated and urban lands in Livermore Valley and the Bay Plain overlie free, unconfined, and confined ground water. Relatively impervious and generally continuous strata exist between the ground surface and the principal pumping aquifers over portions of both Livermore Valley and the Bay Plain. Such strata appear to prevent significant quantities of rainfall, stream flow, or unconsumed irrigation water from percolating to the deeper water-bearing strata. Ground water beneath the impervious strata is generally confined in these aquifers and exhibits pressure characterist

Free and unconfined ground water areas are situated upstream from the confined areas. Free ground water areas are replenished by direct infiltration and percolation of rainfall and stream flow, excesses of applied irrigation water, water discharged into abandoned gravel pits operated specifically for recharge purposes, and by subsurface inflow from the adjacent foothills. They act as forebays to aquifers of the unconfined and confined areas and comprise their principal source of recharge.

The extent of the confined, unconfined, and free ground water areas in Livermore Valley and the Bay Plain was determined by a study of well logs (which indicated the presence or absence of blue clays) from maps showing ground water level elevations; and from results of prior investigations in the area. An area of relativel low permeability in the vicinity of Warm Springs restricts the movement of ground water from the Bay Plain into northern Santa Clara Valley. The westward extent of this area of low permeability is unknown. There may be hydrologic continuity between the Bay Plain and Santa Clara Valley beneath the southern part of San Francisco Bay.

The location and areal extent of the confined, unconfined, and free ground water areas in Livermore Valley and the Bay Plain are shown on Plate 5, entitled "Lines of Equal Elevation of Ground Water--Spring of 1961." Locations of known ground water barrier faults in the Alameda County Area and subdivisions of the ground water producing areas, the boundaries of which are often along these barrier faults, are shown on Plate 6, entitled "Lines of Equal Change in Ground Water Elevation--Fall of 1949 to Fall of 1953;" and Plate 7, entitled "Areal Geology;" as well as on Plate 5.

The faults and ground water subdivisions are described in considerable detail in Appendix C.

Ground Water Geology

Geologic features of the ground water producing areas in the Alameda County Area were investigated. The geologic portion of the investigation, which is reported in detail as Appendix C, included a brief study of the nonwater-bearing rocks, and a more detailed study of water-bearing deposits including a computation of ground water storage capacity.

The Alameda County Area comprises three different physiographic areas: The highlands of the Diablo Range, the intermontane valleys within the Diablo Range, and the San Francisco Bay depression. The highlands of the Diablo Range are composed generally of nonwater-bearing, folded, and faulted rocks ranging in age from the Franciscan formation of the Jurassic period to late Tertiary sediments.

The most prominent valley within the Diablo Range is Livermore Valley, which is a structural basin formed by an east-west trending, faulted syncline or downfold. The southern limb of this syncline is formed by the water-bearing Livermore gravels of Tertiary-Quaternary age which underlie the valley and outcrop in the upland immediately to the south. The Livermore gravels have a maximum thickness of approximately 4,000 feet and consist principally of gravel, sand, and clay. The floor of Livermore Valley is covered by alluvial, lake, and swamp deposits of upper Pleistocene and Recent age, all of which are herein included in the term "late Quaternary alluvium." These deposits consits of gravel, sand, silt, and clay, with an average thickness of about 350 feet. In certain localities the water-bearing properties of the late Quaternary alluvium and underlying Livermore gravels are quite similar.

No folding is known to exist in the late Quaternary alluvium, but three geologic faults affect water-bearing properties of the alluvium and probably the underlying Livermore gravels. The Pleasanton fault trends about N 25° W and passes just east of Pleasanton. Surface expressions of this fault were marked in the low terrace north of U. S. Highway 50 before levelling of the area for construction. A marked water level differential occurs across this fault, ground water elevations being considerable lower on the west side than on the east side. The maximum differential in the fall of 1949 was 50 feet.

The Livermore fault passes southwest of the City of Livermore and trends about N 40° W. Topographic evidence of this fault in the form of scarps and elongated low ridges may be found on either side of the Livermore-Pleasanton Road. A water level differential of up to 100 feet occurred across the northerly part of this fault in the fall of 1949.

The Parks fault trends in an east-west direction in the northern part of Livermore Valley. The trend gradually changes to a northeast-southwest direction in the vicinity of the Pleasanton fault. There is no topographic evidence for this fault but lithologic and water level data indicates its presence and location.

Most wells in Livermore Valley obtain water from the late Quaternary alluvium and the average yield of irrigation wells in the Pleasanton area, where the greatest pumping occurs, is about 500 gallons per minute.

Ground water movement in the upland area south of Livermore Valley is generally toward the valley floor from the southern limb of the Livermore Valley syncline. Limited available evidence from the slope of the water surface, and from the permeability of the sediments, indicates that there is upward movement of ground water from the Livermore gravels into the overlying late Quaternary alluvium. Ground water movement beneath the floor of Livermore Valley is in a general westerly and southerly direction toward the Pleasanton area (Plate 5).

Sunol and Castro Valleys are smaller intermontane valleys in the Alameda County Area. Surface drainage from Livermore Valley passes through the northern end of Sunol Valley on its way to the San Francisco Bay depression. Water-bearing formations in Sunol Valley are the same as those in Livermore Valley, being late Quaternary alluvium and the underlying Tertiary-Quaternary Livermore gravels. Water-bearing materials in Castro Valley consist only of late Quaternary alluvium which has a maximum thickness of approximately 80 feet and is underlain by nonwater-bearing consolidated rock. There are limited data with respect to the number and yield of wells in Sunol and Castro Valleys. Yield from one irrigation well in use in Sunol Valley in 1950 was approximately 250 gallons per minute, most of this water probably being derived from Livermore gravels. The few wells existing in Castro Valley are principally domestic.

The Bay Plain is situated in the San Francisco Bay depression which is in part an irregular downwarp complicated by faulting principally along northwest-trending faults and modified by erosion and deposition. South-westerly from the base of the Diablo Range, the Bay Plain includes an alluvial area close to the highlands, and a marshland area adjacent to the bay. The alluvial area is composed of coalescing alluvial cones, chief among which are, from north to south, the San Leandro, San Lorenzo, and Niles cones. Continuing southward, the Bay Plain includes the Warm Springs alluvial plain, made up of coalescing cones from a number of small creeks, and an older, uplifted and dissected area southeast of Irvington, called the Mission upland, which is underlain by sediments belonging to the Santa Clara formation of Plio-Pleistocene age.

The marshland area consists of a strip of fine-grained deposits up to about three miles in width between the alluvial area and San Francisco Bay. Its contact with the alluvial area is gradational, but can be approximated by the westward limit of agricultural development. The Coyote Hills, an elongated range of low hills composed of consolidated nonwater-bearing rock, protrude into the alluvial and marsh areas west of Newark.

Late Quaternary water-bearing sediments are the uppermost deposits in both the alluvial and marshland areas. These sediments consist of clays, silts, sands, and gravels. The tideland deposits are finer-grained and consist mostly of clay and they interfinger over a broad belt with the alluvial cone deposits. The latter contain a larger proportion of sand and gravel, the grain size generally increasing toward the apexes of the cones at the foot of the uplands. Wells producing from the late Quaternary sediments produce up to approximately 2,000 gallons per minute.

The older Santa Clara formation probably underlies the late Quaternary deposits, and is exposed in the Mission upland area east of the Warm Springs alluvial plain. It consists principally of fine-grained sand and silt with lenticular beds of gravel included. In well logs, sediments of the Santa Clara formation ordinarily cannot be differentiated from those of the overlying late Quaternary alluvium. Wells in the Mission upland area produce up to 400 gallons per minute from the Santa Clara formation.

The Hayward fault crosses the upper part of the Niles Cone between Niles and Irvington. Surface expressions of this fault include a difference in land level, the southwest side being up to 15 feet higher than the northeast side, and elongated depressions and hills along the fault. This fault is a notable barrier to subsurface movement of ground water within the Niles Cone, although some ground water undoubtedly seeps through it and some may move across it at fairly shallow levels. The maximum water level differential across the Hayward fault in 1950 was about 70 feet.

Under natural conditions, ground water in the Bay Plain moved toward San Francisco Bay from areas of recharge at the apex of the alluvial cones adjacent to the highlands of the Diablo Range. The general direction of ground water movement is similar at the present time, with the exception of the Niles Cone. Excessive ground water extractions over long periods of time from deposits underlying this cone have resulted in water levels being lowered below sea level. Landward gradients exist in an upper water producing strata (the Newark aquifer) and intrusion of sea water subsequently has occurred.

Specific Yield and Ground Water Storage Capacity

The term "specific yield," when used in connection with ground water, refers to the ratio of the volume of water a saturated soil will yield by gravity drainage to its own volume, and is expressed as a percentage. Ground water storage capacity is estimated as the product of the specific yield and the volume of material in the depth intervals considered. A study of historic fluctuations of the water table in the Alameda County Area under varying conditions of draft and replenishment permitted a determination of changes of ground water storage in the zones of free and unconfined ground water, and of their safe yield under stated conditions.

Generally, usable ground water storage capacity is limited to zones of free and unconfined ground water, which provide the necessary regulatory storage for draft thereon, as well as for draft on confined zones for which they serve as forebays. Fluctuations in water levels in wells in a confined ground water body represent only changes in pressure surface elevations, and do not indicate changes in ground water storage as long as the water in the aquifer remains under pressure. However, when ground water levels in a confined aquifer are so lowered that the pressure effects disappear, the dewatered portion of the aquifer constitutes usable ground water storage capacity. It is indicated from available evidence that this latter condition has occurred in the Newark aquifer of the Bay Plain and the upper aquifer in Livermore Valley. Computation of ground water storage in these areas has taken this into consideration. With this one exception, determination of specific yield factors and ground water storage capacities in the Alameda County Area was limited to a study of those wells in the free ground water zones.

During studies of ground water in the Alameda County Area, specific yield of different depth zones was estimated after analyzing some 350 well logs. The estimates were based on specific yield values determined by laboratory tests of undisturbed materials, made in previous investigations. Values were then assigned to the various types of material classified in well logs. Ground water storage capacity of Livermore Valley was estimated for depth intervals of 25 to 100 feet, 100 to 200 feet, and for the entire interval from 25 to 200 feet below ground surface. Intrusion of saline water into the aquifers of the Bay Plain imposes a limitation on the depth to which ground water levels could be lowered without probably deleterious effects from saline intrusion. Therefore, ground water storage capacity for that unit was estimated only for depths down to sea level.

Storage capacity of the portion of the ground water basin underlying Livermore Valley and the weighted average specific yield for the stated depth intervals are shown in Table 12.

TABLE 12

ESTIMATED WEIGHTED AVERAGE SPECIFIC YIELD
AND GROUND WATER STORAGE CAPACITY,
LIVERMORE VALLEY

Depth interval, in feet from ground surface	Weighted average specific yield, in percent	Ground water storage capacity, in acre-feet
25 to 100	8.2	195,000
100 to 200	7.1	205,000
25 to 200	7.5	400,000

The estimated usable ground water storage capacity in the Bay Plain, between limits of a filled basin and mean sea level, approximates 33,000 acre-feet. This estimate requires further explanation and qualification. The upper limit of ground water storage was taken as the measured elevation of the water table in February 1914, as published in United States Geological Survey Water-Supply Paper No. 345H, entitled "Ground Water Resources of the Niles Cone and Adjacent Areas, California." The lower limit of storage was taken as mean sea level because of the threat of intrusion of saline water during periods when ground water levels are drawn down to depths below sea level.

The foregoing estimate of ground water storage capacity includes that portion of the Newark aquifer which has been dewatered from time to time in the past. It should be pointed out that ground water levels in the Bay Plain have been drawn down to depths considerably below sea level during recent years. Although ground water storage considerably in excess of the estimated 33,000 acre-feet of estimated usable capacity is presently being utilized, that portion below sea level cannot be considere usable under maintenance of favorable conditions of draft and recharge.

Ground Water Levels

Records of ground water level measurements in the Alameda County Area date back as early as the 1890's. Development of the ground water resources of the Alameda County Area increased rapidly after the turn of the century, particularly in the vicinity of Pleasanton in Livermore Valley, from which large quantities of water were extracted for export to the San Francisco Peninsula, and in the Niles Cone area o the Bay Plain, where irrigated agriculture developed to a high degree. Records of early and recent well measurements in the western portion of Livermore Valley are on file with the San Francisco Water Department. Many early well measurements in the Bay Plain are similarly on file with the East Bay Municipal Utility District. In addition records of early well measurements in the Niles Cone, prior to 1915, have been publish in the previously mentioned United States Geological Survey Water-Supply Paper 345H. The Alameda County Water District has measured and maintained records of depth to wate in the Niles Cone since 1913.

In addition to the foregoing well measurements in the Alameda County Area, well measurements have been made and records thereof have been maintained by the City of Hayward, California Water Service Company, Pleasanton Township County Water District Eden Township County Water District, Citizens Utility Company, and the Alameda County] Control and Water Conservation District.

In connection with the Alameda County Investigation, the Department of Wate Resources made a complete series of measurements of static ground water levels at approximately 450 wells in the Alameda County Area in the spring and fall of each year, beginning in the fall of 1948 in Livermore Valley and in the fall of 1949 in the Bay Plain and continuing through the fall of 1951. In addition, monthly measurements were made at approximately 130 control wells, comprising about 100 wells in the Bay Plain and 30 wells in Livermore Valley. During fall of 1957, spring and fall of 1958, and the spring of 1959, a complete series of water level measurements was made for a salt-water intrusion study in the Bay Plain (Department of Water Resources Bulletin No. 81 "Intrusion of Salt Water Into Ground Water Basins of Southern Alameda County.") The spring and fall well measurement program has continued from the spring of 1952 to the present time on a reduced scale, and includes about 150 wells chosen to form a comprehensive grid covering the entire area. The purpose of these measurements was to observe the behavior of the ground water reservoirs under conditions of draft and recharge. Records of well measurements made during this investigation are on file with the Department of Water Resources.

Lines of equal elevation of ground water (Plate 5) are shown separately for shallow aquifers and for the underlying (deeper) aquifers as these aquifers are separated by strata of impermeable clays which restrict interaquifer exchange of ground water.

Ground water levels in the Alameda County Area undergo monthly and seasonal fluctuations in compensating for the seasonal and cyclic unbalance between replenishment and draft commonly inherent in ground water basin operations. These fluctuations are exemplified in Figures 2 and 3, entitled "Elevation of Ground Water at Representative Wells--Livermore Valley" and "Elevation of Ground Water at Representative Wells--Bay Plain," which illustrate the fluctuation of six wells of long-time record, for the period 1915 through 1954. The locations of these key wells are shown on Plate 5, and numbers have been assigned in accordance with township, range, and section, as described in the foregoing section on precipitation. It will be noted that two of these wells are in Livermore Valley, one being located east of the Pleasanton fault and one west of the fault. Of the four key wells in the Bay Plain, one is located in the free ground water area east of the Hayward fault, one is located in an unconfined ground water area west of the fault, and two are located in the confined ground water area of the Niles and San Lorenzo cones.

Historically, most of the pumping draft in Livermore Valley has occurred in the vicinity of Pleasanton in the western portion of that valley. The factor exhibiting the most marked effect upon ground water levels in the Pleasanton area has been the intermittent heavy pumping by the Spring Valley Water Company and its sucessor, the San Francisco Water Department, for export of water to the San Francisco Peninsula. The effect of this pumping is illustrated in Figure 2 by the hydrograph of well No. 3S/1E-21L1, located west of the Pleasanton fault. A heavy pumping draft on the Pleasanton well field resulted in a severe drawdown of water levels from 1928 to 1934. This drawdown was accentuated by the fact that the water supply (runoff and precipitation) available during this period was only about 50 percent of mean. Complete recovery occurred during the following several years, during which time the water supply was above the mean, and the exporting of water from the well field had ceased. The aquifers remained fully recharged during the ensuing wet period until 1943, when a drought period began which, coupled with increasing agricultural draft, resulted in a gradual decline of ground water levels. The rapid lowering of the ground water levels

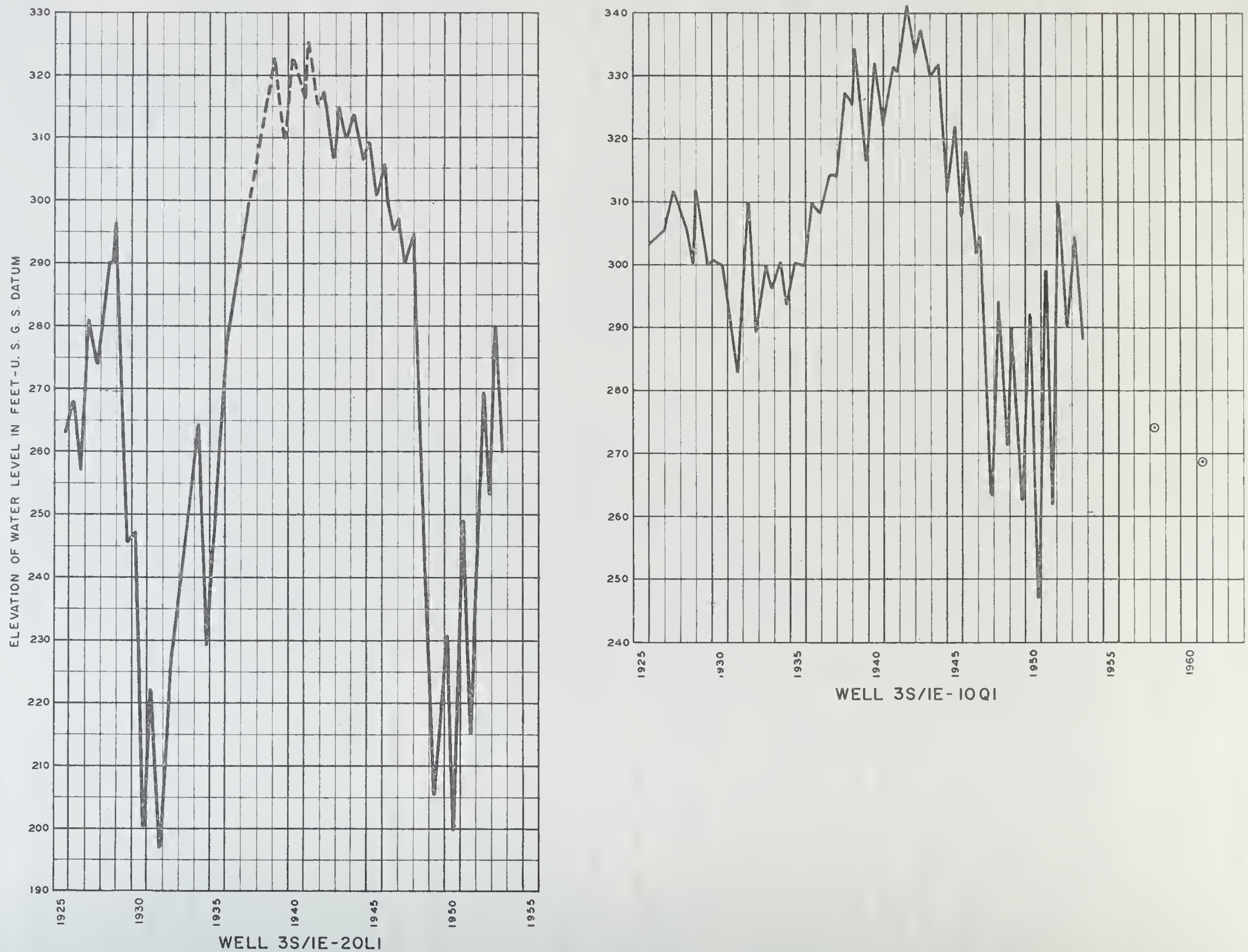


Figure 2. ELEVATION OF GROUND WATER IN REPRESENTATIVE WELLS-LIVERMORE VALLEY

DEPARTMENT OF WATER RESOURCES 1962

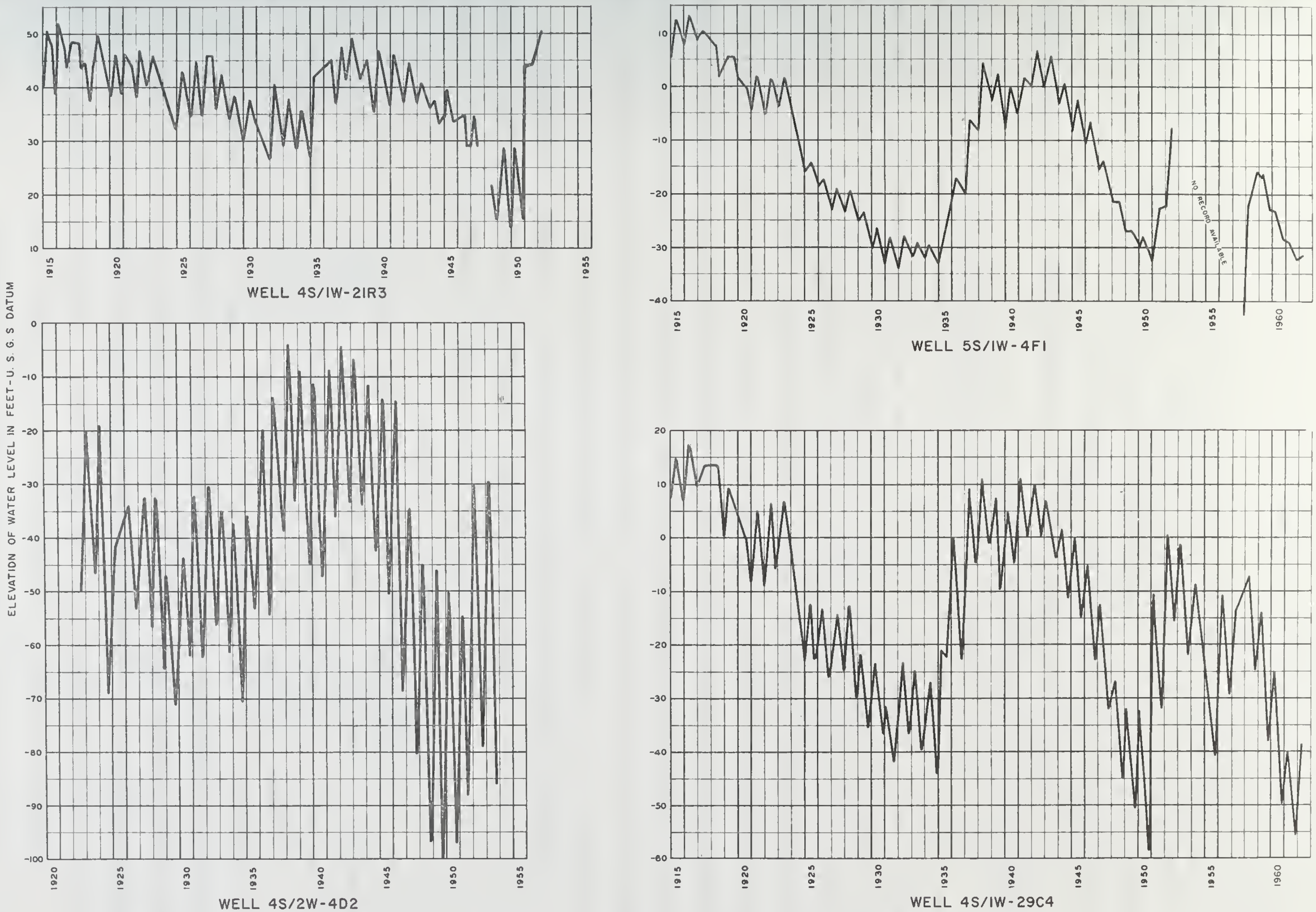


Figure 3. ELEVATION OF GROUND WATER IN REPRESENTATIVE WELLS-BAY PLAIN

DEPARTMENT OF WATER RESOURCES 1962

in the Pleasanton area from February 1948, to May 1949, due to the extraction of some 14,000 acre-feet by the San Francisco Water Department, is clearly evident on the hydrograph of well No. 3S/1E-20L1. Ground water levels showed an upward trend during the wet seasons following 1949.

The hydrograph of well No. 3S/1E-10Q1, located east of the Pleasanton fault, shows a trend similar to that of well No. 3S/1E-20L1, although considerably suppressed in intensity of fluctuation. This hydrograph reflects the cyclic variation of water supply more than the variation in annual pumping draft.

The change in ground water levels in the Alameda County Area during the period of investigation is illustrated on Plate 6.

Ground water levels in the Bay Plain have experienced the same general trend as those in Livermore Valley. The hydrograph shown in Figure 2 of well No. 4S/1W-21R3, located east of the Hayward fault in a free ground water area, shows only a relatively slight fluctuation from season to season. The Hayward fault presents a barrier to the movement of ground water, resulting in a definite restriction of subsurface movement from the easterly to the westerly side of the fault. Because of the Hayward fault and the favorable location of the area east of the fault with respect to recharge from Alameda Creek, ground water levels in that area have generally remained high. However, increases in pumping draft, coupled with the drought period from 1943 to 1950, resulted a substantial decline in ground water levels. Later water-level data show that, during the following wet cycle, ground water levels recovered completely by 1952.

Wells Nos. 4S/2W-4D2, 5S/1W-2F1, and 4S/1W-29C4, located in the confined ground water areas of the Niles and San Lorenzo Cones, all possess very similar hydrographs. Well No. 4S/2W-4D2, a deep well, located in the confined ground water area of t San Lorenzo cone, exhibits considerable fluctuation from spring to fall as well as from year to year. The sharp drop from spring to fall represents pressure relief due to pumping draft. Similarly, the sharp rise from fall to spring indicates the effects or rapid recovery of the pressure surface upon cessation of heavy summer pumping.

A similar condition to that just cited exists for well No. 4S/1W-29C4. This well is perforated in the lower portion of the Newark (upper) aquifer which contains confined ground water; thus the hydrograph represents a pressure surface. The upper portion of this aquifer, which is divided into two parts by a clay layer, contains unconfined ground water. The third well, No. 5S/1W-4F1, is a shallow well situated in the confined ground water area of the Niles Cone. It penetrates the Newark aquifer.

The general trend of the hydrographs of the latter three wells illustrates the cyclic variation in occurrence of water supply in the Bay Plain. By reference o the hydrograph of well No. 4S/1W-29C4, as an example, this general cyclic nature can be illustrated. During the period from 1915 to 1923, ground water levels showed no particular trend except for a slight lowering from 1918 to 1920. However, during the drought period generally prevailing from 1923 to 1935, ground water levels showed a definite downward trend. During the ensuing wet period from 1935 to 1943, ground water levels were restored nearly to their beginning levels of 1915. The drought period, beginning in 1943, and continuing to 1950, resulted in a sharp and rather steady decline of ground water levels. Increases in irrigation draft undoubtedly accentuated this decline. Although the wet seasons subsequent to 1950 brought about a general rise in ground water levels, they remained below sea level, and from spring 1958 to fall 1961 they again sharply declined.

hange in Ground Water Storage

In areas of free and unconfined ground water, the volume of soil dewatered or resaturated over a period of time, multiplied by the specific yield, is a measure of the change in ground water storage during that time. Available data on fluctuations of water levels at wells in the Alameda County Area were sufficient to estimate the volume of soil dewatered or resaturated during the investigational seasons. Changes in ground water storage were estimated for the area by multiplying changes in elevation of ground water by the area over which such changes occurred, and by the average value of specific yield for the depth interval dewatered in each unit.

Changes in ground water storage in Livermore Valley were estimated for the seasons 1948-49 and 1949-50, and for the four-year period 1949-53. These estimates are shown on the following tabulation.

Season	Change in ground water storage in acre-feet
1948-49	-21,400
1949-50	-15,500
1949-53	+14,400

Changes in ground water storage in the Bay Plain were estimated for the period of fall of 1943 to the fall of 1950, and for 1949-52 and 1952-53. These estimates, which include changes in storage in the dewatered Newark aquifer, are presented in the following tabulation.

Period	Change in ground water storage in acre-feet
Fall 1943 - Fall 1950	-90,000
Fall 1949 - Fall 1952	+58,000
Fall 1952 - Fall 1953	-19,000

It will be noted from this tabulation that ground water storage in the Bay Plain decreased by 90,000 acre-feet from the fall of 1943 to the fall of 1950. It has been stated that the estimated usable ground water storage capacity between limits of a filled basin and mean sea level approximates 33,000 acre-feet in the Bay Plain, which means that the greater portion of the ground water utilized during this period was extracted from below sea level. Ground water storage in the Bay Plain in the fall of 1950 was at its lowest recorded stage, with about 70,000 acre-feet having been withdrawn from below sea level. It was during this season that intrusion of saline water into the Newark aquifer became widely observed. Recent water level data have indicated that in the fall of 1961 ground water storage in the Bay Plain decreased to equal that in the fall of 1950.

Subsurface Inflow and Outflow

Under favorable conditions of draft and recharge in the ground water producing areas of the Alameda County Area, wherein ground water levels in the Bay Plain would never be depressed below sea level, the only source of subsurface inflow to those basins would be from movement of ground water from adjacent foothills. However, the draft on the ground water resources of the Bay Plain has increased to such an exten that ground water levels in the Newark and underlying aquifers remain perennially below sea level throughout a large portion of the area. This is evidenced by the ground water contours depicted on Plate 5. This condition has resulted in subsurface inflow to the Newark aquifer from San Francisco Bay, by reason of the landward gradient so established. Conversely, when ground water levels in this aquifer are above sea level, the gradient is reversed, and subsurface outflow toward the bay occurs.

Independent evaluation of the amounts of subsurface inflow to and outflow from the ground water producing areas of the Alameda County Area would be extremely difficult because of the limited available information concerning ground water gradient around the peripheries of the basins and the permeability of materials through which ground water moves. However, these amounts have been evaluated by a method which is described in the following paragraph.

Subsurface inflow from the adjacent foothills, generally from the unmeasured drainage area tributary to Livermore Valley and the Bay Plain, was included in the estimates of surface inflow from those areas, presented in Tables 9 and 10, respectively. Both the surface and subsurface inflow from the adjacent foothills stems from precipitation on those areas. Because both the surface and subsurface inflow constitute an accretion to the water supply of Livermore Valley and the Bay Plain, no attempt was made to evaluate them separately. The combining of surface and subsurface inflow from the adjacent foothills was based on the assumption that subsurface inflow, like surface inflow, is a function of precipitation each season, rather than a function of the ground water levels in Livermore Valley and Bay Plain, or the ground water slope toward those units from the direction of the adjacent foothills.

Derivation of surface and subsurface inflow from the adjacent foothills was based on studies on Chabot Reservoir, which involved correlation of seasonal precipitation on the tributary drainage basin with measured seasonal accretion to the reservoir. A precipitation-inflow correlation curve, plotted from these data, was used in conjunction with estimated seasonal precipitation on the adjacent foothills to determine seasonal surface and subsurface inflow to Livermore Valley and the Bay Plain.

Subsurface Inflow from Beneath San Francisco Bay. Under present conditions of draft in the Bay Plain, with the resultant below-sea-level elevations prevailing in the producing aquifers, subsurface inflow of fresh ground water into deeper aquifers from the direction of San Francisco Bay has constituted a source of ground water replenishment. This can be inferred from the relationship of total pumping extraction from the aquifers to accountable sources of replenishment. Confining clay layers capping the lower aquifers and extending underneath the bay apparently are continuous and are sufficiently impermeable that ground water in these aquifers so far has not been degraded by direct intrusion of sea water. However, subsurface movement of saline water from the bay has occurred through apparent breaks in the upper confining clays. These breaks have permitted the intrusion of sea water into the Newark aquifer, with subsequent infiltration of saline water into certain areas of the deeper aquifers (12). This condition is described in detail in an ensuing section, entitled, "Quality of Water."

The amount of subsurface inflow to the Bay Plain from the direction of San Francisco Bay was derived for the long-time mean period as the quantity necessary to effect a balance between all items of water supply and water disposal. This derivation is presented in Table 13. Certain of the items of disposal utilized in the derivation are presented in Chapter III of this bulletin. The item designated "remainder" in Table 13 would normally include change in ground water storage in addition to subsurface inflow from the direction of the bay. However, assuming the net change in ground water storage to be negligible during the mean period, the remainder would represent the amount of subsurface inflow from the direction of the bay.

It should be pointed out that data on hand do not permit the direct derivation of the amount of subsurface inflow from beneath the bay. As stated, movement of water from this source is concluded from observed ground water slopes and from an inventory of the water supplies available to meet the draft on the aquifers.

TABLE 13

ESTIMATED MEAN ANNUAL SUBSURFACE INFLOW TO BAY PLAIN FROM DIRECTION OF SAN FRANCISCO BAY

(In acre-feet)

Item	Mean period
Water Supply	
Precipitation	33,300
Surface inflow	97,800
Import	10,000
Change in ground water storage	0
TOTAL	141,100
Water Disposal	
Surface outflow	82,400
Mean annual consumptive use of water in free ground water zone	40,200
Present annual water requirement in confined and unconfined zone	35,000
TOTAL	157,600
REMAINDER (Subsurface inflow from direction of San Francisco Bay)	16,500

Subsurface Outflow. Subsurface outflow from Livermore Valley is negligible, due to the outcropping of bedrock in the channel of Arroyo de la Laguna, the only outlet from that valley. It is estimated that subsurface outflow past the gaging station on Arroyo de la Laguna is less than 100 acre-feet per year.

Under present conditions in the Bay Plain, subsurface outflow toward San Francisco Bay is nonexistent. Based on the present stage of development of the ground water producing area, and on the present conditions of recharge supplemented by imported water from the South Bay Aqueduct, it appears that it will require several years before ground water levels will recover to elevations above sea level. Such recovery of ground water levels would be necessary for occurrence of subsurface outflow toward the bay. If ground water levels should recover under future conditions to an elevation where subsurface outflow toward the bay would occur during the winter months, such movement of ground water would probably not constitute a waste. Water moving toward the bay would temporarily serve to repel the advance of saline water, which could later reverse its direction and move inland through the producing aquifer and be pumped during the following summer months.

Quality of Water

Water quality is equally as important as water supply. An abundant supply of water is of no value unless it is of satisfactory quality for beneficial uses.

The mineral quality of surface and ground water in Alameda County varies considerably from place to place and from time to time, but generally is suitable for most beneficial uses throughout the area, with two notable exceptions. In the eastern part of Livermore Valley, high concentrations of dissolved minerals, particularly boron, make most water unsuitable for irrigation, and in the Bay Plain, the intrusion of salt water has rendered some ground water unsatisfactory for most beneficial uses.

Water Quality Criteria

In all activities dealing with observation and measurement of physical data, there must be a yardstick or standard by which the observer, planner, or user can judge or classify the information gathered. With regard to water quality, the problem becomes one of determining whether or not water is suitable for the anticipated use or uses.

Criteria presented in the following sections can be utilized in evaluating mineral quality of water relative to existing or anticipated beneficial uses. It should be noted that these criteria are merely guides to the appraisal of water quality. Except for those constituents which are considered toxic to human beings, these criteria should be considered as suggested limiting values. A water which exceeds one or more of these limiting values need not be eliminated from consideration as a source of supply, but other sources of better quality water should be investigated.

Domestic and Municipal Water Supply

Limiting concentrations of chemical constituents for drinking water, as proposed by the United States Public Health Service and adopted by the State of California, are shown in Table 14.

TABLE 14

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS
1962

Constituent	Mandatory limit in ppm
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Hexavalent chromium (Cr^{+6})	0.05
Cyanide (CN)	0.2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

Constituent	Nonmandatory, but recommended limit
Alkyl benzene sulphanate (detergents)	0.5
Arsenic (As)	0.01
Carbon chloroform extract (exotic organic chemicals)	0.2
Chloride (Cl)	250
Copper (Cu)	1.0
Cyanide (CN)	0.01
Fluoride (F)	1.7
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45
Phenols	0.001
Sulfate (SO_4)	250
Total dissolved solids (TDS)	500
Zinc (Zn)	5

Interim standards for the mineral quality of drinking water have been adopted by the California State Board of Public Health. Based on these standards, temporary permits may be issued for drinking water supplies failing to meet the United States Public Health Service Drinking Water Standards, provided that certain mineral constituents are not exceeded. These interim standards are shown in Table 15.

TABLE 15

UPPER LIMITS OF TOTAL SOLIDS AND SELECTED MINERALS IN
DRINKING WATER AS DELIVERED TO THE CONSUMER

	Permit	Temporary Permit
Total solids	500 (1000)*	1500 ppm
Sulfates (SO_4)	250 (500)*	600 ppm
Chlorides (Cl)	250 (500)*	600 ppm
Magnesium (Mg)	125	150 ppm

* Numbers in parentheses are maximum permissible, to be used only where no other suitable water are available in sufficient quantity for use in the system.

The relationship of infant methemoglobinemia (a reduction of oxygen content in the blood, constituting a form of asphyxia) to nitrates in the water supply has led to the limitation of nitrates in drinking water. The California State Department of Public Health has recommended a tentative limit of 10 ppm nitrogen (44 ppm nitrates) for domestic water. Water containing higher concentrations of nitrates may be considered to be of questionable quality for domestic and municipal use.

The California State Board of Public Health has defined the maximum safe amounts of fluoride ion in drinking water in relation to mean annual temperature. These relationships are shown in Table 16.

TABLE 16

RELATIONSHIP OF TEMPERATURE TO FLUORIDE CONCENTRATION IN DRINKING WATER

Mean annual temperature	Mean monthly fluoride ion concentration
50°F	1.5 ppm
60°F	1.0 ppm
70°F and above	0.7 ppm

Even though hardness of water is not included in the foregoing standards, it is of importance in domestic and industrial uses. Excessive hardness in water used for domestic purposes causes increased consumption of soap and formation of scale in pipes and fixtures. A hardness classification, suggested by the United States Geological Survey, is shown in Table 17.

TABLE 17

HARDNESS CLASSIFICATION

Range of hardness, expressed as $CaCO_3$ in ppm	Relative classification
0 - 60	Soft
61 - 120	Moderately hard
121 - 200	Hard
Greater than 200	Usually requires softening

Industrial Uses

The requirements for quality of water used for industrial purposes are many and diverse, depending on the type of industry and the use to which it is applied.

Quality requirements for food-processing plants, in general, conform to the drinking water standards of the United States Public Health Service listed previously.

Cooling water used in many large industrial processes ordinarily is the least exacting as to quality requirements. The varied processes and conditions existent in industries that could conceivably be ultimately planned for any particular area made it desirable to consider general quality requirements for groups of related industries. These requirements should serve only as guides to a selection of the best or most economical source of water supply for a particular industry.

Table 18 presents water quality values for various industrial uses, as suggested by the committee on Quality Tolerance for Industrial Uses of the New England Water Works Association.

TABLE 18

WATER QUALITY TOLERANCE FOR INDUSTRIAL USES[a]

(Allowable limits in parts per million)

Use	Turbidity	Color	Hardness as $CaCO_3$	Iron[c] as Fe	Manganese as Mn	Total solids	Alkalinity as $CaCO_3$	Odor, taste	Hydrogen sulfide	Miscellaneous Requirements: Health	Miscellaneous Requirements: Other
Air conditioning	-	-	-	0.5	0.5	-	-	Low	1	-	No corrosiveness, slime formation
Baking	10	10	-	0.2	0.2	-	-	Low	0.2	Potable[b]	
Brewing											
Light Beer	10	-	-	0.1	0.1	500	75	Low	0.2	Potable[b]	NaCl less than 275 ppm (pH 6.5-7.0).
Dark Beer	10	-	-	0.1	0.1	1,000	150	Low	0.2	Potable[b]	NaCl less than 275 ppm (pH 7.0 or more)
Canning											
Legumes	10	-	25-75	0.2	0.2	-	-	Low	1	Potable[b]	
General	10	-	-	0.2	0.2	-	-	Low	1	Potable[b]	
Carbonated beverages	2	10	250	0.2	0.2	850	50-100	Low	0.2	Potable[b]	Organic color plus oxygen consumed less than 10 ppm.
Confectionery	-	-	-	0.2	0.2	100	-	Low	0.2	Potable[b]	pH above 7.0 for hard candy.
Cooling	50	-	50	0.5	0.5	-	-	-	5	-	No corrosiveness, slime formation.
Food: General	10	-	-	0.2	0.2	-	-	Low	-	Potable[b]	
Ice	5	5	-	0.2	0.2	-	-	Low	-	Potable[b]	SiO_2 less than 10 ppm.
Laundering	-	-	50	0.2	0.2	-	-	-	-	-	
Plastics, clear,											
Uncolored	2	2	-	0.02	0.02	200	-	-	-	-	
Paper and pulp:											
Groundwood	50	20	180	1.0	0.5	-	-	-	-	-	No grit, corrosiveness.
Draft pulp	25	15	100	0.2	0.1	300	-	-	-	-	
Soda and sulfide	15	10	100	0.1	0.05	200	-	-	-	-	
High-grade light papers	5	5	50	0.1	0.05	200	-	-	-	-	
Rayon (viscose):											
Pulp production	5	5	8	0.05	0.03	100	total 50; hydroxide 8	-	-	-	Al_2O_3 less than 8 ppm, SiO_2 less 25 ppm, Cu less than 5 ppm.
Manufacture	0.3	-	55	0.0	0.0	-	-	-	-	-	pH 7.8 to 8.3.
Tanning	20	10-100	50-135	0.2	0.2	-	total 135; hydroxide 8	-	-	-	
Textiles: General	5	20	-	0.25	0.25	-	-	-	-	-	
Dyeing	5	5-20	-	0.25	0.25	200	-	-	-	-	Constant composition. Residual alumina less than 0.5 ppm.
Wood scouring	-	70	-	1.0	1.0	-	-	-	-	-	
Cotton bandage	5	5	-	0.2	0.2	-	-	Low	-	-	

a-Moore, E. W., Progress Report of the Committee on Quality Tolerances of Water for Industrial Uses: Journal New England Water Works Association, Volume 54, Page 271, 1940.
b-Potable water, conforming to U. S. P.H.S. standards, is necessary.
c-Limit given applies to both iron alone and the sum of iron and manganese.

Irrigation Water

Criteria for mineral quality of irrigation water have been developed by the Regional Salinity Laboratories of the United States Department of Agriculture in cooperation with the University of California. Because of diverse climatological conditions and the variation in crops and soils in California, only general limits of quality for irrigation water can be suggested. These limits are shown in Table 19.

TABLE 19

QUALITATIVE CLASSIFICATION OF IRRIGATION WATER

Chemical properties	Class 1 Excellent to good	Class 2 Good to injurious	Class 3 Injurious to unsatisfactory
Total dissolved solids in ppm	Less than 700	700 - 2000	More than 2000
Conductance, in micromhos at 25°C	Less than 1000	1000 - 3000	More than 3000
Chlorides in ppm	Less than 175	175 - 350	More than 350
Sodium in percent of base constituents	Less than 60	60 - 75	More than 75
Boron in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

These criteria have limitations in actual practice. In many instances a water may be wholly unsuitable for irrigation under certain conditions of use, and yet be completely satisfactory under other circumstances. Consideration also should be given to soil permeability, drainage, temperature, humidity, rainfall, and other conditions that can alter the response of a crop to a particular quality of water.

Preservation and Protection of Fish and Wildlife

Good quality water is necessary for preservation and protection of fish and wildlife. This high quality is necessary not only for the proper environment of fish, but also for maintenance of naturally-occurring food upon which fish depend for survival. There are many mineral and organic substances, in relatively low concentrations, which are harmful to fresh water fish and aquatic life. Quality criteria for water suitable for the maintenance of fresh water fishlife have been suggested by the State Department of Fish and Game as follows:

1. Dissolved oxygen content not less than 85 percent of saturation or 5 ppm.
2. Hydrogen-ion concentration (pH) ranging between 7.0 and 8.5.
3. Ionizable salts as indicated by a conductivity between 150 and 500 micromhos at 25°C and in general not exceeding 1,000 micromhos.
4. Ammonia not exceeding 1.5 ppm.

Fish and aquatic life are particularly susceptible to:

1. Mineral salts of high toxicity, such as those of mercury, copper, lead, zinc, cadmium, aluminum, nickel, trivalent and hexavalent chromium, and iron.
2. Detergents, poisons, and insecticides employed in agriculture.
3. Unusual temperature conditions. Normal range of water temperature for

coldwater fish lies between 32° and $65^{\circ}F$. For warmwater species, a temperature range from 45° to $85^{\circ}F$, with an absolute maximum of 91°.

4. Waste discharges containing more than 15 ppm of ether-soluble material.

Chemical Classification of Water

Water is classified, with respect to mineral composition, in terms of the predominant ions. Specifically, the name of an ion is used where it constitutes at least half of its ionic group, expressed in equivalent weights. Where one ion does not fulfill the requirement, a hyphenated combination of the two most abundant constituents is used. Thus a calcium bicarbonate water denotes that calcium constitutes at least half of the cations and bicarbonate represents at least half of the anions. Where calcium, though predominant, is less than half, and sodium next in abundance, the name is modified to calcium-sodium bicarbonate.

Sources of Data

Basic data in the files of the Department of Water Resources, which were used to evaluate water quality in Alameda County, include several thousand mineral analyses of samples collected from wells and streams since 1950. Interpretation and evaluation of these analyses have been made in several department publications. The report by the Department of Water Resources, entitled "Investigation of Chemical Quality of Surface Water, Waste Discharges and Ground Water, Alameda Creek Watershed Above Niles," presents analyses of water quality in Livermore and Sunol Valleys. Bulletin No. 81, "Intrusion of Salt Water Into Ground Water Basins of Southern Alameda County," presents evaluations of ground water quality in the Bay Plain. Bulletin No. 84, "Recommended Water Well Construction and Sealing Standards, Alameda County," summarizes interpretions of ground water quality data for Livermore Valley, Sunol Valley, and the Bay Plain. In addition, annual Bulletins No. 65, "Quality of Surface Waters in California," and No. 66, "Quality of Ground Waters in California," contain tabulations of analyses of selected streams and wells and summaries of any changes in water quality that may have occurred in a particular area during the preceding year.

Surface Water Quality

Quality and character of surface water in Alameda County vary considerably, both by area and with quantity of flow. In general, the dissolved mineral content of a stream fluctuates inversely with quantity of flow; i.e., mineral concentrations are relatively low at high flows and high at low flows. This is because low flows are generally derived from effluent ground water, which has a greater opportunity to dissolve salts than has rapid runoff from rainfall.

Analyses also may indicate fluctuations in quality at identical flows of a particular stream. For example, samples collected during the early part of the rainy season generally contain greater salt concentrations than samples collected at an identical flow in the latter part of the season, and a sample collected during the rising stage of a flood may contain greater salt concentrations than a sample collected at the same flow during the falling stage. Thus, the quality of a stream varies not only with rate of discharge, but also is influenced by the time of the year or the stage of a flood.

In Livermore Valley, most of the surface water inflow comes from two streams, Arroyo del Valle and Arroyo Mocho, each of which supplies water of good quality. Chemical character of water in these streams ranges from a calcium bicarbonate to a magnesium bicarbonate type. In a normal water year, concentrations of total dissolved solids average less than 250 ppm and boron less than 0.5 ppm. Streams entering Livermore Valley from the east and north generally supply water of poorer quality, ranging in character from a sodium bicarbonate to a sodium chloride type. Total dissolved solids often exceed 1,000 ppm, and one sample from Altamont Creek had a boron concentration of 8.6 ppm. However, flows of this poor quality water are so small that the mixture of all water leaving Livermore Valley via Arroyo de la Laguna closely resembles the good quality water of Arroyo del Valle and Arroyo Mocho.

In the vicinity of Sunol Valley, Arroyo de la Laguna and Vallecitos Creek join Alameda Creek. At this point Arroyo de la Laguna is of slightly poorer quality than Alameda Creek but is less mineralized than Vallecitos Creek, in which boron usually exceeds 1.0 ppm and concentrations of dissolved solids often reach 700 ppm. However, the resultant mixture shows little difference in character or quality from the water in Arroyo de la Laguna, which drains Livermore Valley.

Water in Alameda Creek near Niles, represented by weighted averages in a normal water year, is of very good quality for most purposes. It is of the calcium-magnesium bicarbonate type and moderately hard. In addition to Alameda Creek, lesser sources of surface water discharging onto the Bay Plain are San Lorenzo and Dry Creeks. Although similar in character to the water in Alameda Creek, they generally are higher in dissolved solids but carry smaller concentrations of boron.

Ground Water Quality

The quality and character of ground water in Alameda County varies widely depending upon the geologic formations from which water is derived, the quality of ground water recharge, the extent to which ground water has been affected by pollutants, and the fluctuations resulting from cyclic periods of above normal and subnormal water supply.

Livermore Valley. Quality characteristics of ground water in Livermore Valley largely reflect the quality of surface water from which it is derived. Ground water in the central and southern portion of the valley is replenished principally from percolation of flood waters of Arroyo del Valle and Arroyo Mocho. In general, ground water in this area exhibits a total dissolved solids content of less than 400 ppm, a total hardness content of less than 300 ppm, and a boron content of less than 0.5 ppm. Wells in the northern and eastern portion of Livermore Valley yield water containing higher concentrations of total dissolved solids and boron than wells situated in the western and southern portions of the valley. Boron is particularly notable in this regard as is indicated on Plate 8, entitled "Mineral Characteristics of Ground Water in Areas of Degradation." This plate delineates areas where boron is generally present in well water in concentrations in excess of 0.5 ppm. Plate 8 also shows that small, localized areas of high boron water occur in the central and southern portions of the valley which are areas of generally good quality water. In addition, localized pockets of ground water containing high concentrations of nitrates (in excess of 20 ppm) are scattered throughout the valley.

Sunol Valley. Ground water quality in Sunol Valley has been determined by evaluating analyses of water samples collected from the Sunol filter galleries and from three small domestic wells located in the foothills area immediately adjacent to the valley floor. Compared to the filter galleries, wells of Sunol Valley are a minor source of water supply.

The filter galleries receive water from Sunol Valley gravels through percolation of releases from Calaveras Reservoir, runoff from La Costa Creek, and rainfall on the valley floor. In addition, the galleries receive water through percolation of surface runoff from Livermore Valley and through pipeline deliveries from the Pleasanton well field.

Results of representative samples collected from the Sunol filter galleries, furnished by the San Francisco Water Department, indicate the water is of good mineral quality suitable for most uses. Quality of water from the domestic wells is somewhat inferior to that from the galleries. Concentrations of total dissolved solids range from about 550 to 1,050 ppm in well water but average about 330 ppm in the galleries.

Bay Plain. Native ground water underlying the Bay Plain ranges from a calcium bicarbonate to a calcium-sodium bicarbonate type and is generally of good mineral quality. Although the water generally is suitable for most beneficial uses, boron concentrations in excess of 0.5 ppm occur at several locations, notably in wells situated near zones of geologic faulting. The usability of high boron water for usual agricultural activities is questionable. The highest observed ground water boron concentration was 5.3 ppm in well No. 4S/1W-22M2 near Mission Fault.

With the exception of water in the aforementioned wells located along the fault zone and in wells affected by salt-water intrusion, native ground water derived from shallow wells in the upper aquifer shows a total dissolved solids content ranging from about 350 to 600 ppm. Boron concentrations vary from 0.19 to 0.74 ppm, and chlorides range from 26 to 86 ppm. Percent sodium varies from 26 to 46.

Mineral quality characteristics of native ground water in the lower aquifers of the Bay Plain are essentially the same as those of native ground water in the upper aquifer. Total dissolved solids range from 318 to 575 ppm, and boron varies from 0.12 to 1.00 ppm. Chloride concentration varies from 23 to 98 ppm, and percent sodium ranges from 18 to 69, but generally is less than 60 percent.

Sources of Impairment to Water Quality

Sources of impairment to the quality of water in Alameda County include those of natural origin, domestic and industrial waste, irrigation return water, and sea-water intrusion. A brief dissussion of the cause and character of each of these sources is presented in the following paragraphs. Improperly constructed, defective, and abandoned wells are not actually sources of impairment to ground water quality in themselves but may be important in the transmission of surface waste, drainage water, or leachate from cesspools or septic tanks which could be sources of pollution. Such wells may also provide avenues for interchange of water between aquifers having different quality characteristics. They have caused extensive interchange of salt water from saline upper aquifers of the Bay Plain to lower aquifers generally containing good water.

Natural Sources. Alameda County has a few areas where poor quality water exists due to natural degradation. In the eastern portion of Livermore Valley, both surface and ground water come in contact with a marine formation of Tertiary age which imparts high concentrations of dissolved minerals, especially boron, to the water. In this same area, connate brines under artesian pressure commingle with and degrade meteoric ground water. These two conditions of natural degradation also occur to a lesser extent in other areas of Alameda County.

Another source of natural impairment of water quality is associated with geologic structures, such as faults. The Mission Fault in the Niles Cone area is believed responsible for the highly mineralized water produced from some wells in that vicinity. The poor quality water found adjacent to some faults is probably due to increased mineralization of ground water exposed to fractured rock and mineral material, and to contact with gases and mineralized juvenile water moving up along fault fractures or fissures.

Domestic and Industrial Waste. Disastrous results may be caused by disposal of inadequately treated domestic and industrial waste to streams and to ground water basins. Problems may arise not only from liquid-borne waste but also from the disposal of garbage, refuse, and solid industrial waste. Every effort must be made to maintain the quality of available water by appropriate planning for, and control of, the treatment and disposal of waste, giving consideration to the effect of such waste disposal upon future planned uses as well as the present uses of local water resources. At present, disposal of wastes does not appear to be an immediate threat to the water resources of Alameda County as a whole. In the future, however, with the predicted rapid increase in urbanization and industrialization, careful planning and control of waste disposal will be necessary to prevent serious problems from developing. In the Alameda County Area, responsibility for exercising such control rests with the San Francisco Bay Regional Water Pollution Control Board.

Irrigation Return Water. Evaporation and transpiration consume much of the water applied to irrigated crops with little or no effect on the tonnage of dissolved minerals originally contained in the water. As a result, the portion of applied water that percolates below the root zone contains a higher concentration of dissolved minerals than the water from which is was derived. It has been estimated that the salt concentration in this residual water ranges from two to over eight times that in the water originally applied. Thus, in areas where irrigation return water can percolate to ground water, it may constitute an important source of degradation to the water supply. This applies especially to a closed ground water basin, such as Livermore Valley, which has no subsurface outflow. In Alameda County as a whole, however, irrigation retur waters should become a lesser problem with time, since total irrigated acreage is expected to decrease as urbanization encroaches on agricultural lands.

Sea-Water Intrusion. Water contained in a coastal ground water basin may be subjected to intrusion and admixture of sea water. Intrusion may take place when water-bearing deposits along the seaward or bayward margins of ground water basins are in direct contact with the ocean or bay floor at the shore line, or extend beneath the ocean floor.

Intrusion can occur only when the pressure head of sea water exceeds that of the fresh ground water, a condition usually resulting when ground water levels are lowered to or below sea level by excessive pumping of wells. When the hydraulic gradient within a ground water basin slopes seaward, ground water movement is toward the ocean; conversely, with a landward slope, inland movement of sea water occurs. The slope and direction of the hydraulic gradient is determined by measurements of depth to water

It is believed that the deeper aquifers (below the Centerville aquifer) also gradually are being degraded either directly by intrusion of sea water or indirectly by interaquifer exchange. At present, however, this hypothesis is difficult to prove conclusively, since most of the wells penetrating the Fremont and other deeper aquifers also are perforated in the Centerville aquifer and some even in the shallow Newark aquifer. Of the few wells perforated only in the deeper aquifers on which historic data are available, well No. 4S/1W-30G1, located in Centerville, shows the greatest degree of degradation. This well, with a depth of 451 feet, had a chloride concentration of 23 ppm in the fall of 1953, increasing to 196 ppm in the fall of 1961. However, the Hayward Fault is only two miles from this well, and could conceivably be the dominant factor in the quality of deep ground water in this area.

Any solution or alleviation of the serious problem of sea-water intrusion will be costly and time-consuming. Probably the most efficient remedy would be to supplement the natural recharge with imported water and to restrict pumpage until a seaward gradient of the ground water basin has been established through either natural or artificial recharge of the Niles Cone area.

Adverse Salt Balance

To maintain the ground water quality in a basin it is necessary to establish a balance between salt input to the waters of a basin and salt output. If salt output exceeds salt input, the basin is being leached of salts, and a favorable salt balance exists. Normally this would result in a gradual improvement in overall quality of ground water in the basin. If salt input exceeds salt removal, an adverse salt balance exists, and water quality will deteriorate due to the accumulation of salt. Sources of salt input to the basin water are many, such as, dissolved minerals from soil and rock formations, agricultural fertilizers, domestic and industrial waste, connate brines, and sea water. Normally, the major factors of salt removal are surface and subsurface water outflow and export of water and waste.

Livermore Valley is unfortunate in that it is a closed ground water basin having no appreciable subsurface outflow. Thus, salts can be removed from the basin only by surface outflow through Arroyo de la Laguna or by some artificial means such as exportation. Before the advent of widespread pumping, artesian ground water rose to the surface in the lower portion of the basin near Pleasanton and eventually was discharged from Livermore Valley as surface water. However, this natural leaching process has not occurred in recent years because of the presence of a continual pumping depression in the Pleasanton area.

Presently, a closed ground water basin underlies the Bay Plain. This condition will prevail as long as ground water levels indicate a pumping depression or trough causing a landward hydraulic gradient.

Safe Ground Water Yield

The term "safe ground water yield" refers to the maximum rate of net extractic from a ground water basin which may be sustained over a long period of time without causing certain undesirable conditions. Commonly, safe ground water yield is governed by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water basin must not exceed mean seasonal replenishment to the basin.

2. Water levels must not be so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of degradants or pollutants.

3. Water levels must not be so lowered as to imperil the economy of overlying ground water users by excessive costs of pumping from the ground water basin or by exclusion of the users from a supply therefrom.

Safe ground water yield, as derived in this bulletin, was based on net extraction of water from the free ground water areas, and by gross extraction of water in the confined and unconfined areas. The reason for this difference in measurement in the two different types of areas is that the unconsumed portion of gross pumpage may return to the ground water basin and become available for reuse in free ground water areas, whereas the unconsumed portion of gross pumpage cannot return to the ground water basin for reuse in confined areas.

Both Livermore Valley and the Bay Plain are known to be experiencing an overdraft condition, which means that pumping draft on the ground water resources of those units has increased to a point where it exceeds the maximum seasonal safe ground water yield.

It should be pointed out that when the conditions of the second or third of the foregoing criteria are not being met, it is usually because the conditions of the first criterion had not previously been met.

Based on the foregoing assumption, criteria, and definitions, the safe ground water yield of the Alameda County Area is estimated to be about 44,000 acre-feet per season. This estimate includes the percolation of water delivered by the San Francisco Water Department to the Alameda County Water District for replenishment in the Niles Cone area, and accretions to the ground water basin from delivery of imported water in the Bay Plain by the East Bay Municipal Utility District and the San Francisco Water Department.

The following disucssion and derivation of safe ground water yield of Livermore Valley and the Bay Plain is based upon present development of the surface and ground water resources, and upon the present pattern of water utilization. Such derivation for Sunol Valley was not attempted, because of the operation of that valley by the San Francisco Water Department, wherein the water supply is artificially controlled. No consideration is given in this derivation to the possible effects of further future water development or future changes in the pattern and intensity of water utilization from present sources. Either or both of these factors would modify present safe ground water yield, and would necessitate a re-evaluation of such yield after their effectuation.

Certain of the items included in the estimate of safe ground water yield are based on data and estimates presented in Chapter III. These items include estimates of consumptive use of precipitation and of applied surface water, both of which involve land use survey data and unit values of water use.

Safe Ground Water Yield of Livermore Valley

Under the present pattern of water utilization, average pumping lifts in Livermore Valley are nominal, generally varying between about 25 and 125 feet. However, through the years ground water levels have been falling and it has been determined that the mean seasonal extraction from the ground water basin exceeds the mean seasonal replenishment to the basin. Therefore, the first of the three criteria for determining safe ground water yield is not being met at the present time.

Although there presently exists a water quality problem, as indicated by the presence of relatively high boron concentrations in certain portions of Livermore Valley, there is no evidence to indicate that this problem has become more acute during the investigational period. Continued perennial lowering of ground water levels in Livermore Valley might aggravate the boron problem, in which case the second as well as the first of the three determining criteria would not then be met.

Means of increasing replenishment of ground water supplies in Livermore Valley would lie in the regulation of tributary streams with releases for percolation later in the season after normal stream flow would have ceased, or through importation of water through the South Bay Aqueduct for percolation during the dry season. The estimate of safe annual ground water yield of the valley is presented in Table 21.

TABLE 21

ESTIMATED SAFE ANNUAL GROUND
WATER YIELD IN LIVERMORE VALLEY

(In acre-feet)

Item	Quantity
Mean water supply, under 1951 conditions	
Surface and subsurface inflow	42,100
Precipitation	60,000
Subtotal	102,100
Mean surface outflow, under present conditions	-39,100
Available to meet water requirements	63,000
Mean consumptive use of precipitation	-47,800
Difference	15,200
Adjustment of outflow in Arroyo de la Laguna to compensate for return flow of excess applied water on lands overlying confined zone	+ 1,800
SAFE GROUND WATER YIELD	17,000

It will be noted in Table 21 that a quantity of 1,800 acre-feet, representing return flow of excess irrigation application in the confined zone, is included as an item of safe ground water yield in Livermore Valley. This estimate requires further explanation. It has been previously stated that safe ground water yield was based on net extraction of water from the free ground water areas and by gross extraction of water in the confined and unconfined areas. However, the point at which outflow from the Livermore Valley unit is measured is on Arroyo de la Laguna in the vicinity of Verona Road Bridge, downstream from all areas of water use in that unit. Because of its location, this outflow station records all items of waste from Livermore Valley, including not only runoff of flood flows and of precipitation in that valley, but of return flows from excesses of applied irrigation water on the confined zone. Although these accretions from return flow of excess applications constitute an item of waste from Livermore Valley, they represent a portion of the safe ground water yield of that valley, since such wastes were extracted from the ground water basin and applied to irrigated lands overlying the confined zone. The adjustment shown in Table 21 therefore represents the difference between gross pumping application and consumptive use of applied water for those irrigated lands overlying the confined area.

Safe Ground Water Yield of the Bay Plain

As has been previously stated, present pumping levels in the principal aquifers of the Bay Plain are at considerable depths below sea level in the areas of heavy pumping draft. Geologic data and other information available suggest that the confining clays overlying the lower aquifers and extending beneath San Francisco Bay are continuous beneath the entire south bay. It is entirely possible that there could be a vast storage of fresh water beneath the bay. On the other hand, the storage of fresh water might be dangerously small.

An accounting of logical sources of recharge to the fresh water aquifer underlying San Francisco Bay suggests that such recharge is probably of minor extent. This, in addition to the below-sea-level elevation prevailing in the principal pumping aquifers, leads to the conclusion that the portion of pumping draft in the Bay Plain comprising subsurface inflow from the direction of the bay constitutes a "mining" of ground water, and, as such, cannot be considered a firm supply. Therefore, present draft on the ground water resources of the Bay Plain exceeds the firm seasonal recharge. By reason of this fact the first of the three criteria for determining safe ground water yield is not being met.

The present water quality problem in the Newark and underlying aquifers, and the cause thereof, has been discussed in detail in the preceding section entitled, "Quality of Water." The degradation of quality indicates that the second of the three criteria determining safe ground water yield also has not been met in the Bay Plain. A continuation of present overdraft conditions in the Bay Plain carries the serious threat of widespread degradation of quality of ground water in all of the deeper ground water producing aquifers underlying the area.

During the past several years pumping levels in lower aquifers have remained perennially below sea level over the greater portion of the Bay Plain. A similar condition exists in the Newark aquifer in the Niles Cone. Configuration of water levels in the spring of 1961 is shown on Plate 5, which indicates that elevations from 40 to 80 feet below sea level prevailed in lower aquifers in most of the area of heavy pumping draft. The gradient of the pressure surface of ground water in these lower aquifers is also depicted. It is probable that subsurface inflow from the direction of the bay supplies a substantial portion of the present water requirement in the Bay Plain although no landward gradient is shown by the water level contours on Plate 5.

The safe ground water yield of the Bay Plain, like that of Livermore Valley, has been reached and exceeded under the present pattern of pumping extraction. The portion of pumping draft in excess of safe ground water yield in that unit has been met during recent years by a decrement in ground water storage, in addition to the subsurface inflow from the direction of the bay. Should the present rate and pattern of pumping draft continue over an extended period of time, ground water levels will decline below those occurring at present, and a greater portion of pumping draft in excess of safe ground water yield would be met from subsurface inflow from the direction of the bay. The estimate of safe annual ground water yield of the Bay Plain is presented in Table 22.

TABLE 22

ESTIMATED SAFE ANNUAL GROUND WATER YIELD IN THE BAY PLAIN

(In acre-feet)

Item	Quantity
Mean water supply, under present conditions	
Surface and subsurface inflow	97,800
Precipitation	33,300
Import	10,000
Subtotal	141,100
Mean surface outflow, under present conditions	82,400
Available to meet water requirements	58,700
Mean consumptive use of water, under present conditions	
Precipitation on free ground water area	24,600
Applied surface water on free ground water area	3,100
Application of imported water on confined area	4,000
Subtotal	31,700
ANNUAL SAFE GROUND WATER YIELD	27,000

Certain estimates, presented in the discussion of supplemental water requirements in Chapter III of this bulletin, require a further breakdown of the safe ground water yield of the Bay Plain areas. The first area embraces that portion of the Bay Plain lying south of the northern boundary of the Alameda County Water District, as shown on Plate 4. The other area comprises the remainder of the Bay Plain. Consideration of the distribution of water supply and water use within the Bay Plain, in conjunction with a study of ground water elevation maps, permitted an estimate of the approximate allocation of the safe ground water yield of the two areas. The estimated safe ground water yields of the areas lying south and north of the northern boundary of the Alameda County Water District are 22,000 acre-feet and 5,000 acre-feet, respectively.

It is recognized that a pumping draft equivalent to the estimated annual safe ground water yield of 22,000 acre-feet in the Alameda County Water District would necessitate use of more than the 33,000 acre-feet of available ground water storage capacity above sea level. Data available at the time of the investigation were not sufficient to evaluate the amount of ground water storage required to sustain an annual draft of 22,000 acre-feet. However, it was considered reasonable that a temporary lowering below sea level could be experienced without causing excessive intrusion of sea water into the pumping aquifer, provided that a bayward ground water gradient would later be established.

CHAPTER III

WATER UTILIZATION AND SUPPLEMENTAL REQUIREMENTS

The nature and extent of water utilization and requirements for supplemental water in the Alameda County Area for the present time, for the year 1990, and under conditions of probable ultimate development are considered in this chapter. In connection with the discussion the following terms are used as defined:

Water Utilization -- Any uses of water by nature or man, either consumptive or non-consumptive, as well as irrecoverable losses of water incidental to such uses.

Factors of Water Demand -- Those factors pertaining to specific rates, times and places of delivery of water, losses of water, quality of water, and other factors, imposed by the control, development, and use of the water for beneficial purposes.

Water Requirement -- The amount of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses.

Supplemental Water Requirement -- The water requirement in excess of safe yield of the presently developed local water resources, both surface and underground.

Consumptive Use of Water -- The water consumed by vegetative growth in transpiration and building of plant tissue, evaporated from adjacent soil, water surfaces, foliage, and water similarly consumed and evaporated by urban and nonvegetative types of development.

Applied Water -- The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter, or its equivalent, in the case of urban use. This does not include direct precipitation.

Present -- For purposes of this bulletin, the pattern existing during the field investigational period of 1949-51 was considered present.

Year 1990 -- A year chosen to reflect conditions of development at a future time, between present and ultimate, selected for purposes of planning and designing initial water development projects presented in this bulletin.

Ultimate -- Conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized.

Present water utilization in the Alameda County Area was estimated by application of appropriate unit use of water factors to the pattern of present land use. Water utilization in the year 1990, and under probable ultimate development, was similarly estimated by the use of projected patterns of land use. It is believed that in the year 1990 the Southern Alameda Unit will be almost completely urbanized and urban development will be well advanced in the Livermore Valley and Sunol Valley Units. Under ultimate development conditions, almost all of the area will be urbanized, with irrigated agricultural development limited to highly specialized crops. As indicated by the foregoing definition, requirements for supplemental water were estimated as the differences between derived values of the safe yield of presently developed local water resources and water requirements under both present and ultimate conditions of development.

Certain aspects of water resources development, including flood control, conservation of fish and wildlife, and recreation, will be of varying significance in the design of works to meet supplemental requirements for water in the Alameda County Area. In most instances, the magnitude of nonconsumptive requirements for fish and wildlife, and recreation are relatively indeterminate. Flood control aspects of water developments and water requirements for conservation of fish and wildlife, and recreation are discussed in general terms in this chapter, but are not specifically evaluated.

Water Utilization

Irrigated agriculture in the Alameda County Area became significant around the turn of the century when rural electrification and the development of efficient deep well pumps permitted economical use of ground water. In 1951, about 30,000 acres of irrigated land and 55,000 acres of dry-farmed land were surveyed in this investigation. In the same year there were about 14,600 acres of urban land in the Alameda County Area. The water applied annually to the land at that time amounted to approximately 50,000 acre-feet, while about 21,000 acre-feet supplied the urban demand. Current trends of rapid urban development are expected to continue in the future, and agricultural water use will become less and less important. It is anticipated that eventually practically all water used in the Alameda County Area will be for urban purposes.

Water Supply Development

The water resources of the Alameda County Area are to a large extent develope both by surface storage reservoirs and by utilization of ground water storage. Calaver Dam effectively controls 100 square miles of the Calaveras Creek and Arroyo Hondo drainage areas. In addition, the runoff from approximately 35 square miles of the upper Alameda Creek watershed is diverted through a tunnel into Calaveras Reservoir. Sunol

Dam and filter galleries permit collection of some of the uncontrolled flow in Alameda Creek and tributaries at Sunol. The percolating waters of Arroyo del Valle and of Arroyo Mocho are subject to relatively heavy drafts for irrigation in the Livermore Valley Unit had have in the past been heavily drawn upon by the Spring Valley Water Company and its successor, the San Francisco Water Department. The water of Alameda Creek also supports a heavy ground water pumping draft for irrigation in the Niles Cone area.

Deficient stream flow during the summer months precludes direct surface diversion for irrigation or urban purposes in the Alameda County Area. For this reason nearly all of the local water supplies are obtained from ground water storage. In 1950 there were about 730 wells and pumping plants of heavy draft. A number of additional wells of light draft supplied limited amounts of water for home gardens and orchards and for domestic purposes.

History of Water Supply Development. The development of the water resources of the Alameda County Area has a long and interesting evolution. Historically its water resources have been developed largely for exportation to nearby urban communities as those communities outgrew their local water supplies. Water supply development for use within the Alameda County Area has been primarily by private operation of pumps and wells.

The earliest significant step toward water resource development in the Alameda County Area was taken in 1888 when the Spring Valley Water Company began exporting water from Niles Canyon to San Francisco. In 1898 a series of wells were drilled by that company in the vicinity of Pleasanton, and Sunol Dam on Alameda Creek and the filter galleries in the Sunol Valley gravels were constructed. Water from these sources was conveyed in a pipeline through Niles Canyon and under San Francisco Bay to Crystal Springs Reservoir on the San Francisco Peninsula. Calaveras Dam and Reservoir were constructed on Calaveras Creek by the Spring Valley Water Company and began operating in 1924. Water was released into the natural stream channel and collected in the Sunol filter galleries.

Positive steps were initiated by the City of San Francisco in 1900 toward purchasing the works of the Spring Valley Water Company. The purchase was finally completed March 3, 1930, and included the system on the San Francisco Peninsula as well as the developments on Alameda Creek. These facilities, and others discussed in the following paragraphs, are shown on Plate 4.

Calaveras Reservoir has materially affected the natural ground water replenishment from Alameda Creek in the Niles Cone area. After many years of controversy between the Alameda County Water District and the Spring Valley Water Company over the degree of impairment of percolation by operation of the reservoir, an agreement was reached whereby sufficient releases would be made from the Sunol Aqueduct near Niles to provide replenishment equivalent to that which occurred prior to the construction of the reservoir. Water is released directly into Alameda Creek about one mile upstream from Niles, where it percolates in the stream channel and Shinn Pit, which is an abandoned gravel pit below Niles that has been developed by the Alameda County Water District expressly for ground water replenishment. Additional water is also released directly from the Sunol Aqueduct through a short pipeline into Bunting Pit, another abandoned gravel pit, just south of Niles.

In October 1934, about 20 years from the time of initial construction surveys, water was first delivered through the Hetch Hetchy Aqueduct to the San Francisco Peninsula. The Alameda Creek system is connected with the Hetch Hetchy Aqueduct by a pipeline from Calaveras Reservoir and by a branch pipeline of the Sunol Aqueduct. In 1950 the City of Hayward began receiving water from Hetch Hetchy Aqueduct through its own line from the aqueduct near Irvington.

Until the last few years, all of the cities and towns in the Alameda County Area, except those served by the East Bay Municipal Utility District, have relied entirely on ground water supplies. With the exception of lands owned by the City of San Francisco in the Sunol Valley Unit, all irrigated lands in the Alameda County Area are served water from underground storage.

Present Water Service Agencies. Water for urban and industrial use in the Alameda County Area is furnished by numerous water service agencies which obtain their water supplies from ground water and by import. Water requirements in the Livermore Valley Unit are supplied entirely by direct rainfall and by ground water obtained from pumping wells. Lack of stream flow during the summer and fall precludes unregulated diversion of adequate surface supplies for either agricultural, municipal, or domestic requirements.

The principal water service agencies in the Livermore Valley Unit are the California Water Service Company, the Pleasanton Township County Water District, the San Francisco Water Department, the Valley Community Services District, and Zone 7 of the Alameda County Flood Control and Water Conservation District. In addition to these agencies, there are a number of installations and industries which pump appreciable amounts of ground water, including the Del Valle Hospital, United States Veterans Administration Hospital, the Atomic Energy Commission, Camp Parks, rock and gravel companies, and several large farming enterprises. The areas served by the principal water service agencies are shown on Plate 4.

The California Water Service Company is a privately owned public utility serving the urban area of Livermore and vicinity. In 1949, the company operated six wells, including standby units, and delivered water to 1,593 active services. Water pumped during the period of investigation amounted to about 760 acre-feet in 1948-49, and 800 acre-feet in 1949-50. By 1961, the company was operating 13 wells to produce nearly 3,000 acre-feet for over 5,500 active services.

The Pleasanton Township County Water District is a publicly owned and operated district which serves water in the Pleasanton area. Its principal customer is the City of Pleasanton, which in turn retails water to the consumers in the area. The city has at various times in the past obtained its water from the San Francisco Water Department and from its own wells. The district delivered 475 acre-feet of water from five wells to the City of Pleasanton during 1961. The district recently annexed 4,850 acres and will complete the drilling of an additional well in 1962.

The San Francisco Water Department currently maintains a well field near Pleasanton. Small amounts of water are sold by that department for local irrigation. The greater part of irrigttion and suburban domestic water requirements is supplied by privately owned wells, rather than by organized agencies.

The Valley Community Services District serves an area which lies principally north and west of Camp Parks. Two wells provided about 286 acre-feet for the district's 300 customers during 1961.

The Santa Rita Prison Farm is operated by the County of Alameda, using wells originally drilled by the United States Navy in the Pleasanton area. It serves water for domestic and agricultural uses at the prison farm, located in the former Camp Shoemaker area. In 1952, Parks Air Force Base moved into a portion of the former Camp Shoemaker area. The Air Force base was served water by the county until July of 1953, when the Air Force took over the water supply system and furnished water to the Santa Rita Prison Farm. In 1959, the Department of the Army acquired the base and now operates the water system. Water is pumped from four wells and has varied in quantity from a low of 500 acre-feet in 1951 to a high of 1,583 acre-feet in 1953. Water use in recent years was 757 acre-feet in the 1959-60 fiscal year, 663 acre-feet in 1960-61, and 416 acre-feet in the first half of 1961-62.

The principal water service agency in the Sunol Valley Unit is the San Francisco Water Department, which furnishes water from its Alameda Creek system to the community of Sunol. Irrigated lands owned by the City of San Francisco in that unit are also furnished water from this system. The remainder of the Sunol Valley Unit is furnished water by privately owned wells.

As previously stated, present water service in the Southern Alameda Unit comprises ground water developed by wells, imports via the East Bay Municipal Utility District system from local supplies and from the Mokelumne River, and the Alameda Creek system and Hetch Hetchy Aqueduct of the San Francisco Water Department. The principal water service agencies in that unit are the East Bay Municipal Utility District, City of Hayward, Alameda County Water District, and Citizens Utility Company of California. Also, there are a number of privately owned and mutual water companies which serve water to subdivisions in the unit. In addition to these agencies and companies, there are a number of installations and industries which pump appreciable amounts of ground water. The greater portion of irrigation and suburban water requirements is supplied by privately owned wells rather than by organized agencies.

The East Bay Municipal Utility District serves the principal cities and surrounding urban areas on the east shore of San Francisco Bay. The area served in the Southern Alameda Unit includes the City of San Leandro, the communities of Castro Valley and San Lorenzo Village, and the unincorporated area between San Lorenzo and Hayward. Metered water deliveries for the fiscal years 1951-52 through 1960-61 are presented in Table 23.

TABLE 23

WATER DELIVERIES BY THE
EAST BAY MUNICIPAL UTILITY DISTRICT

(In acre-feet)

Fiscal Year	Total Local System*	Within Alameda County	Alameda County Within Investigational Area**
1951-52	109,225	80,789	10,361
1952-53	113,512	83,066	11,665
1953-54	117,005	84,996	13,310
1954-55	122,885	87,804	14,544
1955-56	127,408	89,115	15,550
1956-57	131,165	91,287	16,814
1957-58	132,616	91,389	17,925
1958-59	149,649	101,995	21,350
1959-60	158,490	103,720	21,912
1960-61	158,699	102,961	22,093

* Excludes water sold by East Bay Municipal Utility District to Vallejo, to San Francisco, and in San Joaquin County.
** Includes all of San Leandro. It is estimated that about 15 percent of these deliveries are outside the investigational area.

The City of Hayward owns and operates its own water supply system, serving water principally for domestic and municipal use. The city furnished water from its own wells and delivered water to 7,671 services in 1950. Since that time, the city has supplemented its ground water pumpage by purchasing water from the San Francisco Water Department's Hetch Hetchy Aqueduct. In 1951 the city pumped approximately 900 acre-feet of water and purchased approximately 1,600 acre-feet from the San Francisco Water Department. Purchases increased from 1,000 acre-feet in 1950 to 5,460 acre-feet in 1957 and further to 7,950 acre-feet in 1961. Total deliveries of water to customers in 1961 amounted to 9,100 acre-feet, including well water.

The Alameda County Water District is publicly owned and operated, and serves water in Washington Township in the Southern Alameda Unit. There are approximately 30,000 acres in the district irrigated from privately owned wells. The district served water to approximately 2,600 domestic services in 1952, 7,400 services in 1956, and about 12,600 services in 1960 from its own wells and by water purchased from the Hetch Hetchy Aqueduct. In 1951, these purchases amounted to about 200 acre-feet. An additional 200 acre-feet were purchased from the aqueduct by individual industries in the Alameda County Water District. Total water produced by the district amounted to 875 acre-feet in 1952, 2,600 acre-feet in 1956, and about 6,200 acre-feet in 1960.

The Citizens Utilities Company of California is a privately owned water company which serves nearly 2,900 customers in the Decota-Niles area. The company operates six wells from which about 560 acre-feet of water was delivered in 1952, about 715 acre-feet in 1956, and nearly 1,080 acre-feet in 1961. The company is developing two new wells, and anticipates serving 400 to 500 additional customers by mid 1963.

Land Use

As a first step in estimating present water requirements in the Alameda County Area, determinations were made of the nature and extent of land use prevailing during the investigational seasons. Similarly, land use in the year 1990, and under probably ultimate development conditions, as related to water requirements were forecast on the basis of data obtained from a survey of habitable areas made in connection with studies for State Water Resources Board Bulletin No. 2. In the survey of habitable areas, lands were classified in accordance with their suitability for urban development.

Present Land Use. Comprehensive land use surveys of the Livermore Valley Unit were made in 1949 and 1951, and of the Southern Alameda Unit in 1949, 1950, and 1951, the latter survey including urban developments in and adjacent to Castro Valley.

The Sunol Valley Unit was surveyed in 1951. The land use surveys utilized maps prepared by combining field lines and ownership lines from aerial photographs and county assessor's maps, utilizing United States Geological Survey topographic maps for control. For purposes of this bulletin, the pattern existing during 1951 was considered to represent "present" conditions of land use. Results of the 1951 land use survey are summarized in Table 24. Urban and irrigated lands in 1951 in the Livermore Valley, Sunol Valley, and Southern Alameda Units, including Castro Valley and environs, and ultimate habitable lands in the Alameda County Area are shown on Plate 9, entitled "Present and Probable Ultimate Water Service Areas."

TABLE 24

PRESENT PATTERN OF LAND USE
IN UNITS OF ALAMEDA COUNTY AREA (1951)

(In acres)

Class and type of land use	Livermore Valley Unit: Confined ground water zone	Livermore Valley Unit: Free ground water zone	Livermore Valley Unit: Total	Sunol Valley Unit	Southern Alameda Unit: Confined ground water zone	Southern Alameda Unit: Free ground water zone	Southern Alameda Unit: Total	Totals
Irrigated Lands								
Alfalfa	440	320	760	40	550	80	630	1,430
Beans	0	0	0	0	1,140	360	1,500	1,500
Flowers	80	290	370	0	240	210	450	820
Grain	0	580	580	0	0	0	0	580
Orchard	0	1,090	1,090	180	1,290	2,750	4,040	5,310
Pasture	900	550	1,450	90	1,390	560	1,950	3,490
Sugar beets	80	610	690	0	1,610	310	1,920	2,610
Tomatoes	190	1,580	1,770	0	3,610	1,140	4,750	6,520
Truck	60	350	410	140	3,860	2,430	6,290	6,840
Vineyard	0	760	760	0	20	40	60	820
Subtotals	1,750	6,130	7,880	450	13,710	7,880	21,590	29,920
Nonirrigated Lands								
Grain and pasture	1,320	27,850	29,170	1,230	16,280	4,510	20,790	51,190
Orchard and vineyard	20	1,680	1,700	0	320	190	510	2,210
Trees and brush	0	190	190	70	260	260	520	780
Truck	240	690	930	0	0	0	0	930
Subtotals	1,580	30,410	31,990	1,300	16,860	4,960	21,820	55,110
Urban								
Airfield	0	0	0	0	250	0	250	250
Industrial	0	220	220	0	430	110	540	760
Residential and commercial	280	2,790	3,070	10	6,210	4,320	10,530	13,610
Subtotals	280	3,010	3,290	10	6,890	4,430	11,320	14,620
Miscellaneous								
Farm lots	70	440	510	0	650	320	970	1,480
Highway and railroads	50	780	830	40	960	320	1,280	2,150
Roads	80	600	680	0	480	340	820	1,500
Wasteland	20	880	900	0	50	100	150	1,050
Water surface	0	210	210	0	70	110	180	390
Subtotals	220	2,910	33,130	40	2,210	1,190	3,400	6,570
TOTALS	3,830	42,480	46,290	1,800	39,670	18,460	58,130	106,220

Year 1990 and Probable Ultimate Land Use. Estimates of future land use in the Alameda County Area were made for two stages of development. The first stage is an intermediate period between the present time and ultimate, and was used as a guide in planning initial projects for water development. As stated previously, the second stage comprises ultimate development. The term "ultimate" refers to conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum, and essentially stabilized. It is realized that any forecasts of the nature and extent of such ultimate development, and resultant water utilization, are inherently subject to possible large errors in detail and appreciable error in the aggregate. However, such forecasts, when based upon best available data and present judgement, are of value in establishing long-range objectives for development of water resources. They are so used herein, with full knowledge that their re-evaluation after the experience of a period of years may result in considerable revision.

The year 1990 was selected for determination of land use of the first of the foregoing two future stages of development, inasmuch as it allows a reasonable repayment period for initial water development projects. Furthermore, the magnitude of initial water development projects necessary to meet the water requirements during this period would probably not exceed the limits of present financial feasibility.

As a prerequisite to the evaluation of land use in the Alameda County Area in the year 1990, future population trends were considered. The Livermore Valley and Sunol Valley Units were considered together, since growth in these units will probably be closely related. The estimated population in the year 1990 is 320,000 in the Livermore Valley and Sunol Valley Units, and 680,000 in the Southern Alameda Unit. A portion of the urban development associated with the estimated population in the year 1990 will occur on the foothill lands of the Southern Alameda Unit, particularly around Castro Valley and Hayward. Similar development is expected to occur in in the foothills adjacent to the western portion of Livermore Valley.

In determining the amonnt of land which would be required for urban purposes in the year 1990, it was necessary to develop estimates of probable over-all urban densities. Consideration was given to the present population densities on different types of terrain, and also to the opinions of experts in the urban planning field. Population densities ranging from 14 persons per acre in the vicinity of Hayward and Castro Valley to 6.0 persons per acre on the rolling foothills were assigned. A density of 11 persons per acre was generally assigned to the relatively flat lands which would be readily utilized for urban types of development. From these studies it was determined that the weighted average population density in the year 1990 would be about 9.6 persons per acre in the Livermore Valley and Sunol Valley Units, and about 10.0 persons per acre in the Southern Alameda Unit. The urban areas are estimated to be about 33,000 acres in the Livermore and Sunol Valley Units and 68,000 acres in the Southern Alameda Unit.

Since urban development in and adjacent to the Southern Alameda Unit will be very extensive, it will probably eliminate most irrigated agriculture except intensive types, such as greenhouse and high-value nursery stock, by the year 1990. Some irrigated agriculture will probably remain in the Livermore Valley Unit by that year, as urban development will not have reached a stage comparable to that in the Southern Alameda Unit. It is estimated that about 5,000 acres, devoted to high-value truck crops, will be under irrigation in the Livermore Valley Unit in the year 1990.

The forecast of probable ultimate land use in the Alameda County Area was based mainly on the previously cited studies made in connection with State Water Resources Board Bulletin No. 2. As stated, it is anticipated that all of the habitable area will be largely urbanized under probable ultimate development, because of the proximity of the Alameda County Area to the metropolitan center of the San Francisco Bay Area. Estimates of potential ultimate water service areas included consideration of the types of land required for urban and irrigated agriculture. Although the Livermore Valley and Sunol Valley Units and the surrounding foothills will be highly urbanized, it is believed that under probable ultimate development some irrigated agriculture, such as greenhouse, nursery, and high-value truck crops, will persist. It is conceivable that zoning for agriculture will keep a limited acreage in agricultural production.

The estimated pattern of lands requiring water service in the Alameda County Area for the year 1990 and under probable ultimate development are summarized in Table 25 by general classes of land use. The location and areal extent of potential probable ultimate water service areas is shown on Plate 9.

TABLE 25

PROJECTED PATTERN OF LANDS REQUIRING WATER SERVICE IN ALAMEDA COUNTY AREA IN YEAR 1990 AND UNDER PROBABLE ULTIMATE DEVELOPMENT

(In acres)

Unit and class of land use	Year 1990	Probable ultimate
Livermore Valley and Sunol Valley Units		
Urban	33,000	83,000
Irrigated land	5,000	4,500
TOTALS	38,000	87,500
Southern Alameda Unit		
Urban	68,000	72,000
Irrigated lands	0	0
TOTALS	68,000	72,000

In addition to the lands requiring water service as shown in Table 25, there is a fringe of salt ponds and marshlands, as well as the Coyote Hills, located along the westerly boundary of the Southern Alameda Unit. These lands, which are shown on Plate 9, are considered susceptible of urban and industrial development in a pattern similar to that projected for the Southern Alameda Unit. About 75 percent of these lands, or some 17,000 acres, is presently devoted to the production of salt, while the remaining 25 percent is undeveloped and comprises about 5,600 acres of marshlands and 600 acres of hills. The possibility of development of these lands, as related to the requirement for delivery of water, is very uncertain. Therefore, the projections for the year 1990 were based on no development. However, at some future time it is probable that urban and industrial development will absorb all of these lands, including those presently utilized for the production of salt. The probable ultimate urban area requiring water service in the Southern Alameda Unit with development of the foregoing lands would be 95,200 acres.

Unit Use of Water

The second major step in the evaluation of present, of the year 1990, and of probable ultimate water requirements in the Alameda County Area involved determination of appropriate unit values of water use for each class of land requiring water service. In addition, certain phases of the hydrologic analyses required determination of use of water by native vegetation and other lands not requiring intensive water service

Present Unit Use of Water. Derivation of unit values under three different concepts of water use was necessary to the hydrologic analyses and evaluations of present water requirements in the Alameda County Area. The first concept is that of the total consumptive use of water, including use of precipitation necessary to the detailed hydrologic analysis for the purpose of evaluating all items of the hydrologic equation, under present conditions of development.

A procedure suggested by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service, United States Department of Agriculture, in their reports entitled "A Method of Estimating Water Requirements in Irrigated Areas from Climatological Data," dated December 1947, and "Determining Water Requirements in Irrigated Areas From Climatological and Irrigation Data," dated August 1950, was generally utilized for adjustment of available data on unit consumptive use by irrigated crops in other localities, to correspond with conditions existing in the Alameda County Area. This method involved correlation of the data on the basis of variations in average monthly temperatures, monthly percentages of annual daytime hours, percipitation, and length of growing season. It disregarded certain generally unmeasured factors, such as wind movement, humidity, etc. Average monthly temperatur at Livermore and at Newark were considered representative of the Livermore valley and Southern Alameda Units, respectively. Monthly percentages of annual daytime hours were determined for latitude 37° 30' N., which passes approximately through the center of the Alameda County Area.

Following is an outline of the procedure utilized for estimating unit values of consumptive use of water.

1. The unit value for each irrigated crop during its growing season was taken as the product of available heat and an appropriate coefficient of consumption, where: (a) available heat was the sum of the product of average monthly temperatures and monthly percent of daytime hours, and (b) the coefficient of consumption was one which had been selected as appropriate for California by Harry F. Blaney as a result of his studies for the Soil Conservation Service.

2. The unit value for each irrigated crop during its nongrowing season was taken as the amount of precipitation available, but not exceeding one to two inches of depth per month, depending on the type of crop.

3. The annual unit value for each irrigated crop was taken as the summation of values determined under items 1 and 2 for that crop.

4. Annual unit values for native annual grasses were taken as the summation of available precipitation up to but not exceeding two inches in depth per month.

5. Annual unit values for native vegetation, other than annual grasses, were estimated on the basis of available data on corresponding consumptive use in similar localities, due consideration being given to density and type of vegetation and depth to ground water.

6. Annual unit values for free water surfaces were estimated from available records of evaporation at Newark.

7. Annual unit values for all classes of urban development were taken from studies made in connection with State Water Resources Board Bulletin No. 2.

8. Annual unit values for remaining miscellaneous types of land use were estimated on the basis of available data on corresponding consumptive use in similar localities.

TABLE 26

ESTIMATED UNIT VALUES OF MEAN ANNUAL CONSUMPTIVE USE
OF WATER IN ALAMEDA COUNTY AREA

(In feet of depth)

Class and type of land use	Livermore Valley Unit			Southern Alameda Unit		
	Applied water	Precip-itation	Total	Applied water	Precip-itation	Total
Irrigated Lands						
Alfalfa	2.6	1.2	3.7	2.1	1.5	3.6
Beans	0.8	0.8	1.6	0.6	1.2	1.8
Flowers	1.2	1.0	2.2	0.7	1.2	1.9
Grain	1.2	0.9	2.1			
Orchard	1.7	1.2	2.9	1.5	1.3	2.8
Pasture	2.3	1.2	3.5	2.1	1.2	3.3
Sugar beets	1.5	0.9	2.4	1.1	1.2	2.3
Tomatoes	1.3	0.9	2.2	1.0	1.2	2.2
Truck	1.5	0.9	2.4	1.1	1.2	2.3
Vineyard	1.2	0.9	2.1	0.9	1.2	2.1
Nonirrigated Lands						
Grain and pasture	---	1.1	1.1			1.2
Orchard and vineyard	---	1.1	1.1			1.2
Trees and brush	1.4	1.1	2.5	1.4	1.2	2.6
Truck	---	0.9	0.9			---
Urban a/						
Airfield	---	0.4	0.4	0.4	0.4	0.8
Industrial	1.5	0.5	2.0	9.0	0.7	9.7
Residential and commercial	1.5	0.5	2.0	0.9	0.8	1.7
Miscellaneous						
Farm lots	0.9	1.1	2.0	0.8	1.2	2.0
Highway and railroads	---	0.6	0.6			0.7
Roads	---	0.6	0.6			0.7
Wasteland	---	0.7	0.7			0.7
Water surface b/	---	---	4.0			0.7

a/ Unit values apply to gross areas of urban development, including streets and other paved surfaces, and vacant lots.
b/ Evaporation.

Estimated annual unit values of consumptive use of water in the Alameda County Area, including values for consumption of both applied water and precipitation (presented in Table 26) are considered to be representative of annual unit consumptive use during the mean period.

The second concept of water use referred to is the seasonal consumptive use of applied water. Such use is a measure of the requirement for water, other than precipitation, in zones of free ground water, wherein water applied in excess of consumptive use requirements will return to ground water and be available for reuse. The chosen unit values were derived by subtraction of computed values of consumptive use of precipitation from appropriate total unit values of consumptive use, described in the foregoing paragraph. Unit values of seasonal consumptive use of applied water are also presented in Table 26.

In the confined zones of the Livermore Valley and Southern Alameda Units, wherein water applied in excess of consumptive use is largely prevented from returning to ground water storage for subsequent reuse, the measure of water requirement was taken as the amount of applied water. As stated at the beginning of this chapter, the term "applied water" as used in this bulletin, refers to that water other than precipitation which is delivered to a farmer's headgate or from his well and pump, in the case or irrigation use, or which is delivered to an individual meter, or its equivalent, in the case of urban use. Unit values of water applied to irrigated lands were determined from data on pump operation collected during each season of the investigation, and from records of electrical energy consumption furnished by the Pacific Gas and Electric Company.

Records of application of water pumped from wells irrigating selected plots of principal crops grown on various soil types in the Alameda County Area were obtained for 20 plots in 1949, 32 plots in 1950, and 21 plots in 1951. For each well the pump discharge, acreage of each type of crop irrigated, and rate of power consumption were recorded. The total seasonal application of water to each crop, so derived, was devided by the acreage of each crop to obtain the seasonal unit application of water. Detailed results of these studies are included as Appendix E to this bulletin, and the locations of the plots are indicated on Plate 9.

As an alternative method of deriving unit values of applied water, monthly records of electrical energy consumption by irrigation pumps, furnished by the Pacific Gas and Electric Company, were utilized in conjunction with measured and estimated pumping plant efficiencies and average monthly pumping lifts to obtain total seasonal application. By dividing total seasonal applications by the crop acreages, unit values of application of water were obtained. From both these and the foregoing plot studies, unit seasonal values of water applied to the various crops in the Alameda County Area were evaluated. These derived values are presented in Table 27.

TABLE 27

ESTIMATED MEAN ANNUAL UNIT APPLICATION OF WATER TO IRRIGATED AND URBAN LANDS IN ALAMEDA COUNTY AREA

(In feet of depth)

Class and type of land use	Livermore Valley Unit	Southern Alameda Unit
Irrigated lands		
Alfalfa	3.9	3.1
Beans	---	1.1
Flowers	2.3	1.3
Grain	1.2	---
Orchard	3.2	2.0
Pasture	3.3	3.1
Sugar beets	2.8	1.9
Tomatoes	2.5	1.4
Truck	2.8	1.7
Vineyard	2.3	1.2
Urban*		
Residential and commercial	1.5	0.9
Industrial	1.5	9.0
Farm lots	0.9	0.8

* Unit values apply to gross areas of urban development, including street and other paved surfaces, and vacant lots.

In evaluating the unit use of water delivered to urban areas, the assumption was made that all such areas overlie zones of confined ground water, since, with the exception of the City of Livermore, all sewage is conveyed away from the areas of use by conduit. This assumption is on the conservative side, because ground water replenishment in those urban areas overlying the free ground water zones is neglected. However, the application of water to lawns and gardens in those areas from which ground water replenishment could occur is practiced sparingly. Moreover, the areas on which such replenishment could occur comprise less than 50 percent of the areas classified as urban in Table 24.

Present unit water requirements by urban lands in the Alameda County Area were developed from data secured from the East Bay Municipal Utility District and other agencies on delivery of water for municipal and industrial purposes. These data were also basic to the derivation of unit values of urban water requirements utilized in preparation of State Water Resources Board Bulletin No. 2. These unit values are presented in Table 27, which shows residential and commercial, and industrial applications of water.

Year 1990 and Probable Ultimate Unit Use of Water. Because of the anticipated future trend from irrigated agriculture to urban development and the uncertainty involved in any projections of specific classes of urban development, it was necessary to make projections of future unit uses of urban areas which would reflect a weighted value for all types of use.

Estimates of the water requirements of the Alameda County Area in the year 1990 were made on a per capita basis in conjunction with the previously cited studies basic to the preparation of State Water Resources Board Bulletin No. 2. It is indicated that the water requirements in the Livermore Valley and Sunol Valley Units will be 136 gallons per capita per day in the year 1990. The corresponding requirement in the Southern Alameda Unit in that year is estimated to be 129 gallons per capita per day. Based on a forecast population density of 9.6 persons per acre and 10.0 persons per acre in the Livermore Valley and Southern Alameda Units, respectively, the weighted annual unit values of applied urban water in the foregoing units would be 1.46 feet and 1.45 feet, respectively. Studies made in connection with Bulletin No. 2 indicate a loss in an urban water distribution system amounting to about 10 percent of the metered delivery. Therefore, the foregoing unit values were increased by 10 percent, to 1.61 feet and 1.58 feet to represent deliveries to the Livermore Valley and Southern Alameda Units, respectively. Estimates of the probable ultimate unit water delivery in the Alameda County Area were taken directly from data utilized in the preparation of State Water Resources Board Bulletin No. 2.

The estimated unit water requirements for irrigated lands, in the year 1990 and under probable ultimate patterns of land use in the Alameda County Area, was taken as 1.5 feet. As previously stated, it has been assumed that irrigated lands, both in the year 1990 and under probable ultimate development, will be limited to the Livermore Valley and Sunol Valley Units, and that such lands will comprise principally high-value truck crops.

Estimated values of unit delivery of water in the Alameda County Area for the year 1990 and for probable ultimate development are presented in Table 28.

TABLE 28

ESTIMATED MEAN ANNUAL UNIT VALUES OF WATER DELIVERY IN ALAMEDA COUNTY IN YEAR 1990 AND UNDER PROBABLE ULTIMATE DEVELOPMENT

(In feet of depth)

Unit and class of land use	Year 1990	Probable ultimate
Livermore Valley and Sunol Valley Units		
Urban	1.61	2.41
Irrigated land	1.5*	1.5*
Southern Alameda Unit		
Urban	1.58	2.48
Irrigated land	----	----

* Consumptive use of applied water; irrigated lands assumed in free ground water area.

Present Water Requirements

The total present water requirement in the Alameda County Area was estimated by multiplying the area of each type of land use by its appropriate unit value of water use, presented in a foregoing section of this chapter.

The estimated present seasonal consumptive use of water in the Livermore Valley Unit, and in the free ground water zone of the Southern Alameda Unit, determined as a requisite to the evaluation of safe ground water yield of the Alameda County Area, is summarized in Table 29 by principal classes of land use. The values shown represent the products of areas of land use in those zones, taken from Table 24, and appropriate unit values of seasonal consumptive use of water, taken from Table 26.

TABLE 29

ESTIMATED PRESENT (1951) MEAN ANNUAL CONSUMPTIVE USE OF WATER IN LIVERMORE VALLEY UNIT AND IN FREE GROUND WATER ZONE IN SOUTHERN ALAMEDA UNIT

(In acre-feet)

Class of land use	Livermore Valley Unit			Southern Alameda Unit		
	Applied water	Precipitation	Total	Applied water	Precipitation	Total
Irrigated lands	13,100	8,100	21,200	10,000	11,600	22,100
Nonirrigated lands	300	35,000	35,300	400	7,000	7,400
Urban	4,800	1,800	6,600	4,900	4,500	9,400
Miscellaneous	500	2,900*	3,400	300	1,500*	1,800
TOTALS	18,700	47,800	66,500	15,600	24,600	40,200

* Includes evaporation from water surface.

As stated in a foregoing section on unit use of water, the measure of present water requirement in the Alameda County Area was taken as the amount of consumptive use of applied water in the free ground water zones and the amount of total applied water in the confined zones.

The present water requirement in units of the Alameda County Area are summarized in Table 30 by principal classes of land use. The values shown for water requirement in the free ground water zones represent the products of areas of land use, taken from Table 24, and appropriate units of use of applied water, taken from Table 26. Similarly, the values for present water requirement in the confined ground water zones represent the products of areas of land use in those zones from Table 24 and appropriate unit values of applied water from Table 27.

TABLE 30

ESTIMATED PRESENT (1951) MEAN ANNUAL WATER REQUIREMENT IN UNITS OF ALAMEDA COUNTY AREA

(In acre-feet)

Class of land use and source of water service	Livermore Valley Unit: Free ground water zone	Confined ground water zone	Total	Southern Alameda Unit: Free ground water zone	Confined ground water zone	Total	Total
Ground Water							
Irrigated lands	9,400	5,600	15,000	10,000	24,900	34,900	49,900
Nonirrigated lands	300	-----	300	400	------	400	700
Urban	4,500	400	4,900	1,800	5,600	7,400	12,300
Miscellaneous	400	100	500	300	500	800	1,300
Subtotals	14,600	6,100	20,700	12,500	31,000	43,500	64,200
Surface Water							
Urban	------	-----	------	3,100	4,000	7,100	7,100
TOTALS	14,600	6,100	20,700	15,600	35,000	50,600	71,300

Year 1990 and Probable Ultimate Water Requirements

The estimates of water requirement in the Alameda County Area in the year 1990 and under probable ultimate development have been determined by applying appropriate unit values of water delivery to areas of projected land use. These estimates are summarized in Table 31, by general classes of land use. These values represent the products of the acreages of land use, shown in Table 25, and the appropriate unit values of water delivery, as shown in Table 28.

TABLE 31

ESTIMATED MEAN ANNUAL WATER REQUIREMENTS IN ALAMEDA COUNTY AREA IN YEAR 1990 AND UNDER PROBABLE ULTIMATE DEVELOPMENT

(In acre-feet)

Unit of class of land use	Year 1990	Probable ultimate
Livermore Valley and Sunol Valley Units		
Urban	54,000	200,000
Irrigated land	8,000	7,000
Subtotals	62,000	207,000
Southern Alameda Unit		
Urban	107,000	179,000
Irrigated land	0	0
Subtotals	107,000	179,000
TOTALS	169,000	386,000

The probable ultimate mean annual water requirements in the Southern Alameda Unit with the development of marshlands and salt ponds would be increased by some 58,000 acre-feet to a total of 237,000 acre-feet per year. The total water requirement in the Alameda County Area would thus be increased to 444,000 acre-feet per year under this condition of ultimate development.

Nonconsumptive Water Requirements

Certain nonconsumptive requirements for water, such as those for flood control, recreation, and conservation of fish and wildlife, will be of significance in the design of works to meet consumptive requirements for water in the Alameda County Area. In most instances the magnitudes of these nonconsumptive requirements are relatively indeterminate, and are dependent upon allocations made during design of the works and after consideration of economic factors. Water requirements for flood control, recreation, and conservation of fish and wildlife are discussed in general terms in this section, but are not specifically evaluated.

Flood Control. Destruction and havoc caused by floods in California have frequently been accompanied by the economic anomaly of wastage of large amounts of water from areas of deficient water supply. Storage of such flood waters in upstream reservoirs would have accomplished the dual purpose of conservation of needed water and reduction of flood damages. Results of the statewide water resources investigation indicate that if California is to attain growth and development commensurate with her manifold resources, nearly all of the potential reservoir storage capacity of the State must be constructed and dedicated to operation for water conservation purposes. This in itself will result in a substantial increase in downstream flood protection. However, any portion of the available reservoir storage capacity that is operated wholly or partially for flood control purposes will correspondingly reduce the capacity available for conservation.

Historic floods of the past have inundated relatively large areas of the Livermore Valley and Southern Alameda Units. The principal areas subject to this flooding have been agricultural lands along the lower reaches of San Lorenzo and Alameda Creeks and in the western portion of the Livermore Valley. This flooding by bank overflow and levee overtopping can generally be attributed to decreased channel capacity, which results from the flatter grades in the lower stream reaches, and also from silting.

In past years, levees have been constructed along portions of San Lorenzo and Alameda Creeks by local interests. However, they were maintained inadequately, and were subject to breaching by relatively small floods. Bank revetments, constructed by local agencies and land owners, have been only partially successful in preventing bank erosion and consequent loss of property. Recently, the United States Army Corps of Engineers, in cooperation with the Alameda County Flood Control and Water Conservation District, completed a flood control project on San Lorenzo Creek. The channel extends from San Francisco Bay to Foothill Boulevard. These works provide protection against a flood greater than the maximum flood of record.

The Corps of Engineers has completed an investigation of the flood problems along Alameda Creek and in the western portion of Livermore Valley. The report on this investigation states that a channel with a capacity of 52,000 second-feet, extending from Niles to the Bay, and a flood control reservation of 35,000 acre-feet in Del Valle Reservoir, to be constructed by the State as part of the South Bay Aqueduct, will control the standard project flood in the Coastal Plain reach of Alameda Creek. The report recommends that the channel be authorized for construction by the Corps of Engineers and that a cash contribution be made to the State for the flood control reservation in Del Valle Reservoir. The report also states that channel improvements in Livermore Valley are not economically justified at this time (1962) and recommends that they not be authorized.

The State has reviewed this report and concurs with conclusions except that it recommended that channel improvements in Livermore Valley be re-evaluated. The United States Congress has authorized the project essentially as formulated by the Corps of Engineers.

LIVERMORE VALLEY FLOODING
December 24, 1955
(Pleasanton - Upper Right, Camp Parks - Left)

ALAMEDA CREEK FLOODING
December 24, 1955
(Niles in Background)

Aerial Photographs Courtesy
Alameda County Flood Control and
Water Conservation District

The Alameda County Flood Control and Water Conservation District, formed in 1949, is the local public agency empowered to participate in flood control and water development. This district has, to date, authorized projects for flood control and local drainage in Southern Alameda County with a total estimated cost of about $32,000,000. So far, expenditures on these projects have been about $20,000,000.

Fish, Wildlife, and Recreation. Sport fishing in the Alameda County Area is largely restricted to San Francisco Bay and the lower portion of Alameda Creek. A small amount of trout fishing is done in the headwaters of such streams as Alameda Creek, Arroyo Mocho, Arroyo del Valle, and Calaveras Creek. Municipal water supply reservoirs such as Lake Chabot and Calaveras Reservoir all have large potentials for sport fishing, but are closed to the public at present. Allowance of controlled public fishing in these reservoirs, as is being done successfully in many municipal reservoirs in the United States, would increase the sport fishing opportunities in the area several fold. The East Bay Municipal Utility District is, at present, considering opening Lake Chabot to fishing.

Alameda Creek supports a limited run of steelhead trout, and is planted with catachable trout during the summer trout season by the California Department of Fish and Game. The 1960 allotment for this stream was 28,000 fish, giving it a major role in this type of fishing.

The water development projects in the Alameda Creek drainage would serve to reduce peak flood flows in lower Alameda Creek. In addition, they could provide sustained late spring and summer flows which could enhance the natural population of steelhead, and would permit the Department of Fish and Game to continue its trout planting program.

Incentive to provide recreation opportunities at reservoirs is afforded throu the Davis-Grunsky Act which enables the Department of Water Resources to made grants to local agencies for that portion of the construction costs of a project which are proper allocated to recreation. Under provisions of this act, the Alameda County Flood Contro and Water Conservation District has applied for grants of $184,250 for allocated costs Cull Creek Reservoir and $150,750 for San Lorenzo Creek Reservoir. The department has concluded that these amounts would be justified and is processing the applications (November 1962).

Factors of Water Demand

Factors of water demand, as used in this bulletin, pertain to rates, times, and places of delivery of water, losses of water, quality of water, and other factors, imposed by the control, development, and use of water for beneficial purposes.

As urban demands increase in importance, the resultant demand characteristics will overshadow the irrigation demand characteristics. As previously stated, it is anticipated that the demand characteristics in the Alameda County Area will be essentially those of urban uses by the year 1990, and agricultural demands will have relatively minor role. Although the irrigation demands during the next two decades will be relatively important, it is assumed that these demands will have been reduced to minor proportions by the time the peak capacity of initial water development works is required. Therefore, consideration was given only to monthly urban demands in the preliminary designs of works to meet supplemental water requirements.

Monthly Demands for Water. The demand schedule for the service area of the East Bay Municipal Utility District was considered representative of the urban demand for water in the Bay Plain. The demand schedules for the Livermore area, both present and ultimate, were estimated by the Alameda County Flood Control and Water Conservation District. These monthly urban demands are presented in Table 32, in percentages of the annual total.

TABLE 32

ESTIMATED AVERAGE MONTHLY DISTRIBUTION
OF ANNUAL DEMAND FOR URBAN WATER

Month	Demand in Percent		
	Bay Plain*	Livermore Valley**	
	Present	Present	Ultimate
January	6.8	4.7	6.1
February	6.1	4.5	5.9
March	7.2	5.0	6.3
April	8.2	7.0	7.5
May	9.2	8.5	8.8
June	10.0	12.4	10.8
July	10.4	13.8	11.2
August	10.3	13.0	11.0
September	9.5	11.9	10.5
October	8.5	8.0	8.7
November	7.0	6.5	7.0
December	6.8	4.7	6.2
TOTAL	100.0	100.0	100.0

* Data from East Bay Municipal Utility District for 1948-51 considered representative of uses in the Bay Plain.

** Estimated by the Alameda County Flood Control and Water Conservation District, for Zone 7.

Supplemental Water Requirements

The previously presented data, estimates, and discussions regarding water supply and requirements in the Alameda County Area indicate that water supply problems are limited largely to those connected with ground water. Although the effects of these problems in the past and at the present time are largely related to irrigated agriculture, it is anticipated that their future effects will concern urban development. It is further indicated that ground water problems created by general lowering of ground water levels in the Alameda County Area, and intrusion of sea water into the aquifers of the Southern Alameda Unit, may be limited if adequate supplemental water supplies are developed and utilized in the area. The estimated present, year 1990, and probable ultimate requirements for supplemental water in the Alameda County Area are discussed and evaluated in the following sections. As previously defined, requirements for supplemental water refer to the amount of water, over and above the sum of present safe ground water yield and safe surface water yield, which must be developed to satisfy water requirements. Water requirements in turn refer to the amount of water needed to provide for all beneficial consumptive uses of water and for irrecorveable losses of water incidental to such beneficial uses.

Present Supplemental Water Requirement

The present requirement for supplemental water in the Alameda County Area was evaluated as the difference between safe yield of the presently developed water supply and the present water requirement. However, it was stated in Chapter II that the only source of water supply other than that developed from ground water storage comprises imported water supplies which can be increased as requirements increase in the areas served therefrom. Therefore, the present requirement for supplemental water in the Alameda County Area represents the difference between safe ground water yield and the present use of ground water.

It was estimated in Chapter II that the safe seasonal ground water yield in the Alameda County Area amounts to 44,000 acre-feet, including 27,000 acre-feet in the Southern Alameda Unit, and 17,000 acre-feet in the Livermore Valley Unit. It was further estimated that the safe ground water yield of that portion of the Southern Alameda Unit lying south of the northern boundary of the Alameda County Water District, generally comprising the area for which future sources of water supply must be developed approximates 22,000 acre-feet. These values were determined as the seasonal use of water from the ground water basins which might be maintained, under mean conditions of water supply and climate.

The total annual requirement for water developed from underground storage in the Alameda County Area, with the present pattern of land use and under mean conditions of water supply and climate, was estimated to be 64,200 acre-feet, as shown in Table 30.

This requirement is distributed as follows: Livermore Valley Unit, 20,700 acre-feet; and Southern Alameda Unit, 43,500 acre-feet. The estimated present requirement for supplemental water in the Alameda County Area totals 20,200 acre-feet per season, which total comprises 3,700 acre-feet for the Livermore Valley Unit, and 16,500 acre-feet for the Southern Alameda Unit.

Year 1990 and Probable Ultimate Supplemental Water Requirements

The requirements for supplemental water in the Alameda County area in the year 1990 and under probable ultimate development were evaluated as the difference between present safe ground water yield and the water requirements under conditions of development at the times considered. Development and utilization of supplemental water supplies in the amounts of these forecasts would assure an adequate supply of water for lands presently receiving water service, as well as for those additional lands which will receive water in the future.

The derivation of year 1990 and probable ultimate requirements for supplemental water in the Alameda County Area, particularly those in the Southern Alameda Unit, have been predicated on certain assumptions regarding future water service. The area in the Southern Alameda Unit lying north and west of Hayward, and including Castro Valley, is presently served water by the East Bay Municipal Utility District. This area is shown on Plate 4. The City of Hayward has been purchasing increasing quantities of water from the San Francisco Water Department during recent years, and recently entered into a long term contract for future water supplies from that department. It is believed that the area lying north of the northern boundary of the Alameda County Water District will obtain its full supplemental supply from the East Bay Municipal Utility District and the San Francisco Water Department.

The area lying generally south of Alvarado, although presently undergoing a change from agricultural to urban development will be more extensively urbanized as imported water is made available. This area is largely within the boundaries of the Alameda County Water District. The district is engaged in distributing water and is preparing plans for an expansion of present water service within its boundaries. For these reasons, the areas requiring supplemental water service in the Southern Alameda Unit in the year 1990 and under probable ultimate conditions have been limited in this study to the area lying south of the northern boundary of the Alameda County Water District.

In a foregoing section entitled "Year 1990 and Probable Ultimate Water Requirements," the mean seasonal water requirement in the Southern Alameda Unit in the year 1990 was estimated to be 107,000 acre-feet for a weighted average population density of 10.0 persons per acre on 68,000 acres. However, the population density in the area north of the northern boundary of the Alameda County Water District is expected to be greater than the population density in the area south of that boundary. The resultant mean seasonal water requirements of the two areas in the year 1990 are estimated to be 48,000 acre-feet and 59,000 acre-feet, respectively. Under conditions of probable ultimate development it is anticipated that the unit water requirement will be uniform throughout the Southern Alameda Unit. The seasonal water requirements in the northern and southern portions of that unit are estimated to be about 77,000 acre-feet and 102,000 acre-feet, respectively, without development of the salt ponds and marshlands, and 80,000 acre-feet and 157,000 acre-feet, respectively, with development of salt ponds and marshlands. The estimated supplemental water requirements in the northern and southern portions of the Southern Alameda Unit in the year 1990, and under probable ultimate conditions of development, are summarized in Table 33.

Table 33

ESTIMATED ANNUAL SUPPLEMENTAL WATER REQUIREMENTS IN NORTHERN AND SOUTHERN PORTIONS OF SOUTHERN ALAMEDA UNIT IN YEAR 1990 AND UNDER PROBABLE ULTIMATE DEVELOPMENT

(In acre-feet)

Item	Year 1990			Probable ultimate*		
	Northern portion	Southern portion	Total	Northern portion	Southern portion	Total
Total water requirement	48,000	59,000	107,000	77,000	102,000	179,000
Less safe ground water yield	-5,000	-22,000	-27,000	-5,000	-22,000	-27,000
Imported supply from East Bay Municipal Utility District and San Francisco Water Department	43,000	------	43,000	72,000	------	72,000
Supplemental water requirement**	0	37,000	37,000	0	80,000	80,000

* Does not include development of salt ponds and marshlands, which would increase the ultimate supplemental requirements for the southern portion to 135,000 acre-feet per year.

** The estimates do not reflect deliveries from the South Bay Aqueduct which were begun in June 1962.

The total water requirements and supplemental water requirements in the year 1990 and under probable ultimate conditions of development in the Livermore Valley and Sunol Valley Units and in the southern portion of the Southern Alameda Unit, are summarized in Table 34. As indicated in that table, the supplemental water requirements are derived by subtracting the present safe ground water yield from the total water requirements.

TABLE 34

ESTIMATED ANNUAL SUPPLEMENTAL WATER REQUIREMENTS IN ALAMEDA COUNTY AREA IN YEAR 1990 AND UNDER PROBABLE ULTIMATE DEVELOPMENT

(In acre-feet)

Item	Year 1990			Ultimate		
	Livermore Valley and Sunol Valley Units	Southern Alameda Unit	Total	Livermore Valley and Sunol Valley Units	Southern Alameda Unit	Total
Total water requirement	62,000	107,000	169,000	207,000	179,000	386,000
Less safe ground water yield	-17,000	-27,000	-44,000	-17,000	-27,000	-44,000
Imported supply from EBMUD and SFWD	----	-43,000	-43,000	----	-7,000	-7,000
Supplemental water requirement (without development of salt ponds and marshlands)1/	45,000	37,000	82,000	190,000	80,000	270,000
With development of salt ponds and marshlands	45,000	37,000	82,000	190,000	135,000	325,000

1/ The estimates do not reflect deliveries from the South Bay Aqueduct which were begun in June 1962.

CHAPTER IV. PLANS FOR WATER DEVELOPMENT

The present water supply problems in the Alameda County Area consist of overdrafts on the ground water supplies in Livermore Valley and the Bay Plain. In addition to resultant continued lowering of ground water levels, these overdrafts carry the threat of mineral degradation of the ground water of Livermore Valley, and have resulted in serious degradation of the ground water in the principal pumping aquifers of the Bay Plain by intrusion of sea water from San Francisco Bay. Elimination of these problems, prevention of their recurrence in the future, and provision of water to lands not presently served will require importation of water from an outside source or sources.

It is estimated that the present (1951) requirement for supplemental water in the Alameda County Area averages about 20,200 acre-feet per season exclusive of water supplies from the South Bay Aqueduct. Anticipated future growth in the area will ultimately require the development of supplemental water in the mean seasonal amount of about 270,000 acre-feet. The supplemental requirements would be increased to about 325,000 acre-feet with development of the salt ponds and marshlands along the easterly shore of San Francisco Bay.

Sources of supplemental water are available locally in runoff that presently wastes to San Francisco Bay from the Alameda Creek system. It is estimated that this waste would have averaged about 70,000 acre-feet annually, had the present (1951) pattern of land use and water supply development prevailed during the mean period. However, studies made during this and other investigations indicate that even the fullest practicable development of local water resources in the Alameda County Area would fail to meet the present supplemental water requirement, and that importation of water from outside sources is required to meet present deficiencies and future demands. There remains little opportunity for future increased conservation development on the Alameda Creek system, except as described later in this chapter, because of the absence of suitable reservoir sites below the confluences of Alameda Creek and its several tributaries, and because of the prior development of some of the major tributaries for export of water to the San Francisco Peninsula. Descriptions of various plans considered for the conservation and utilization of local water supplies and the development of imported water supplies to meet the future water requirements of the Alameda County Area are presented in this chapter under the headings: "Conjunctive Operation of Surface and Underground Storage," "Plans for Local Water Development" and "Plans for Importation of Water."

All elevations hereinafter presented are references to mean sea level, United States Geological Survey datum, established in 1929. This datum is also used on topographic maps published by that agency.

Conjunctive Operation of Surface and Underground Storage

The term "conjunctive operation," as used in this bulletin, refers to the coordinated operation of surface reservoirs and underground storage, and involves planne operation of underground storage, wherein variable seasonal ground water replenishment is regulated to uniform seasonal extraction. Conjunctive operation, therefore, involves consideration of long-time carry-over, or "cyclic" underground storage. Basically, such operation involves the detention of runoff in surface storage reservoirs only for the time required for regulation of releases to rates which can be absorbed in downstream channels for replenishment of ground water storage.

The yield developed by conjunctive operation of surface and underground storage is predicated on the criterion that the average seasonal draft on the ground water basin must be sufficient so that adequate unused storage capacity will be available in the ground water basin to accept surface water for storage. The effects of such operation, with attendant increased use of water from the ground water basin, is manifested in a greater depletion in ground water storage during drought periods, thus creating additional usable storage space for filling during wet periods.

Development of increased yield through conjunctive operation generally requires much smaller capital expenditures than the surface storage necessary to develop comparable amounts of supplemental water. In addition, as compared with water in surface storage, the evaporation losses in ground water basins are negligible. From a practical standpoint, however, there are certain considerations which must be recognized in any plan for conjunctive operation of surface and ground water storage.

Runoff in the Alameda County Area fluctuates widely from season to season. This fact is illustrated graphically in Figure 1 (page 24), which also shows a general cyclic trend in the occurrence of runoff during the mean period. As shown in Figure 1, there are series of consecutive seasons during which the water supply is generally belo the mean. There are also shown to occur a series of consecutive seasons during which the water supply is generally substantially above the mean. Conjunctive operation of surface and underground storage, therefore, involves the capture of runoff, as it occurs, by surface reservoirs and the transfer of this water to underground storage during the same season, by regulation of flows to rates within the percolation capacities of downstream channels.

The draft on the ground water basin, on the other hand, would vary between elatively narrow limits from season to season, and for all practical purposes can e considered uniform. With conjunctive operation, the ground water basin would fill uring wet periods, when the replenishment would exceed the draft, and would be rawn down during drought periods, when the draft would exceed the replenishment. umping lifts in Livermore Valley would, therefore, vary between wider limits than hose which have occurred in the past, especially toward the end of a drought period.

Due to relatively small amount of usable ground water storage capacity in he Bay Plain, conjunctive operation is not contemplated by the Alameda County Water istrict in its plans for development of local water and for use of South Bay Aqueduct ater.

Under any plan involving conjunctive operation of ground water storage in he Livermore Valley Unit there exists a potential water quality problem. Increased owering of ground water levels resulting from large cyclic fluctuations might cause ateral flow of waters of inferior quality, rising along fault zones, with resultant egradation of ground water which would otherwise be of good mineral quality.

The success of planned operation of the ground water basin in utilizing he yield developed by conjunctive operation of surface and underground storage would e contingent upon the voluntary participation by the overlying ground water users, nd the operation of the project by a basin-wide or county-wide water service agency.

Plans for Local Water Development

Preliminary reconaissance surveys were conducted at nine potential dam and eservoir sites in the Alameda County Area. The following streams were considered o have possible development potential: Arroyo del Valle, Arroyo Mocho, Tassajara reek, Alamo Creek, Cottonwood Creek, and an unnamed creek in Collier Canyon, all ributary to Livermore Valley; San Antonio Creek, tributary to Sunol Valley; and an Lorenzo and Dry Creeks, tributary to the Bay Plain.

It was concluded that in the Livermore Valley Unit the widely variant runoff f Tassajara, Alamo, and Cottonwood Creeks, and the unnamed creek in Collier Canyon, ould be insufficient to develop a satisfactory firm seasonal water supply. Therefore, eservoir storage development on those streams would not be justified. This is articularly true in the case of the latter two streams. Furthermore, topography n Alamo and Tassajara Creeks is unfavorable for construction of dams to the height ecessary for development of adequate storage. The runoff of Dry Creek, which is ributary to the Bay Plain, was also considered to be insufficient to justify reservoir torage development. Full development of San Lorenzo Creek is limited by the very rapid urbanization of potential reservoir sites, and would prove very expensive for the small amount of local water which would be developed. For these reasons, large-scale development of the foregoing streams was given no further consideration. However, the Alameda County Flood Control and Water Conservation District is initiating construction of relatively small dams on San Lorenzo and Cull Creeks with a total estimated new yield of about 400 acre-feet annually.

Of the nine streams given preliminary reconnaissance study, only three are considered favorable for possible development. These are Arroyo del Valle, Arroyo Mocho, and San Antonio Creek. The mean seasonal runoff of Arroyo Mocho is about the same as that of Alamo Creek, but the storage site considered on Arroyo Mocho is favorably located with respect to the highly absorptive gravels in the downstream channel as it traverses the Livermore Valley. This condition makes possible the conjunctive operation of a surface reservoir on Arroyo Mocho with ground water storage, thus requiring considerably smaller surface storage to develop a given yield than that storage which would be required without such conjunctive operation. The storage site considered on Arroyo del Valle is similarly favorably located.

In connection with the ensuing discussion, the term "safe yield" is defined as the maximum sustained rate of draft that could be maintained from a reservoir, through a period of critically deficient water supply, to meet a given demand for water for irrigation, urban, or other beneficial purposes. However, in the case of coordinated operation of surface and underground reservoirs, referred to as "conjunctive operation," safe yield is defined as the average combined seasonal yield that could be obtained from both surface and underground storage over the mean period 1894-95 through 1946-47. The term "new yield" is defined as that portion of the safe yield resulting from conservation by a new development of water which otherwise would have wasted from the area without the new development.

Plans for development of Arroyo del Valle, Arroyo Mocho, and San Antonio Creek are described in the following sections, and have been designated the "Del Valle Dam and Reservoir," "Mocho Dam and Reservoir" and "San Antonio Dam and Reservoir," respectively. Their locations are shown on Plate 4.

Del Valle Dam and Reservoir

Construction of a dam and reservoir on Arroyo del Valle is proposed as an integral part of the authorized South Bay Aqueduct. It will provide regulatory storage permitting deliveries of water to be made to project service areas on a variable demand basis. The proposed dam site is located about five miles south of Livermore in Section 3, Township 4S, Range 2E, M.D.B. & M.

The dam, as planned, will be a 202-foot high earthfill structure with a concrete lined, chute-type spillway and flip basin, and will impound a maximum of about 74,000 acre-feet of water. This storage includes 35,000 acre-feet for flood control, 29,000 acre-feet for regulation, 5,000 acre-feet for silt detention and 5,000 acre-feet for fish enhancement. During the nonflood season, 1,000 acre-feet of the flood control capacity will be available for regulation. In addition to regulation of imported water and protection of the downstream areas from floods, Del Valle Reservoir will provide large potential for recreation and fishery enhancement.

The area to be inundated is covered with grass, brush, and oak trees and is used principally for grazing cattle. Man-made improvements in the reservoir area include a county road and a power transmission line. About four miles of each of these will require relocation. Another structure within this area is a 376-foot deep, concrete-lined vertical shaft, owned by the City of San Francisco. The shaft, which measures approximately six feet by eighteen feet, was used during the construction of the Coast Range Tunnel of the Hetch-Hetchy Aqueduct. Since completion of the aqueduct in the early 1930's, the shaft has been used as an access to the tunnel for maintenance. It is anticipated that it may be used again during construction of a parallel tunnel, and subsequently will be used for maintenance of both tunnels. Modification and protection of this shaft will be required.

The Alameda County Water District and the Pleasanton Township County Water District have water rights permits to develop unappropriated water from Arroyo del Valle. These permits are equal in time and afford an equal share of the water which might be developed under them. In recognition of the plans of the California Department of Water Resources for construction of Del Valle Dam and Reservoir as a feature of the South Bay Aqueduct, the two districts signed an agreement with the department on November 29, 1957, in which it was agreed that a plan for development of unappropriated local water would be formulated and a subsequent agreement prepared defining the manner of operation of the reservoir. Studies are being conducted by the department on the feasibility of operating Del Valle Reservoir in conjunction with the South Bay Aqueduct and ground water storage in Livermore Valley and the Bay Plain. Detailed plans for operation and conveyance of locally conserved water have not yet been finalized (June 1962).

Mocho Dam and Reservoir

Development of Arroyo Mocho by construction of a dam and reservoir at the Mocho site, and conjunctive operation of this project with the ground water basin of the Livermore Valley, could provide new yield to meet a portion of the estimated present supplemental water requirements in the Livermore Valley Unit. The Mocho site is located about 5.7 miles southeast of the City of Livermore, in Section 1, Township 4S, Range 2E, M.D.B. & M. The principal features of the proposed Mocho project are shown in Figure 5.

The proposed Mocho Dam would be a 65-foot high earthfill structure with a chute-type spillway. Streambed elevation at this site is 785 feet. Water would be released through the dam into the channel of Arroyo Mocho at rates not exceeding the percolation capacity of the channel (estimated to be 30 second-feet) for replenishment of the ground water basin underlying the Livermore Valley. A distribution system was not considered necessary because the new yield developed by Mocho Reservoir would be pumped from the ground water basin by use of existing and future wells.

As a first step in determination of the optimum size of the Mocho Dam and Reservoir, estimates were made of the yield of the proposed works for various storage capacities. It is estimated that the 53-year mean seasonal runoff of Arroyo Mocho, from approximately 39 square miles of watershed above the dam site, is about 4,000 acre-feet. However, about half of the 53-year total runoff comprises flood flows which occurred during eight seasons, and which in the main part wasted from the area. In contrast, it is indicated that all or nearly all of the runoff has percolated in the stream channel during most of the remaining seasons. The present mean seasonal ground water replenishment from Arroyo Mocho is estimated to be about 1,700 acre-feet. In order to effect maximum conservation a large reservoir would be required for long-term carry-over of the runoff of the few wet seasons. Therefore, it was concluded that operation of relatively small reservoir in conjunction with downstream ground water storage would constitute the most practicable means of developing additional yield on Arroyo Mocho.

Based on preliminary geological reconnaissance, the Mocho dam site is considered suitable for an earthfill dam of any height up to 120 feet. The site lies in the terraced gravels of the Livermore-Tassajara formation of the Plio-Pleistocene age. The semiconsolidated materials immediately underlying the site can be classified as very soft. Subsurface exploration is needed to determine the type and depth necessa to prevent leakage. Sufficient quantities of mixed soil and gravel are available in th reservoir area for construction of the dam. This material, with sorting, would be adequate for both the pervious fill and the impervious fill. Material suitable for rip-rap would require approximately a 10-mile haul. The aggregates necessary for concrete work would be available from one of several gravel plants in the Livermore Valley.

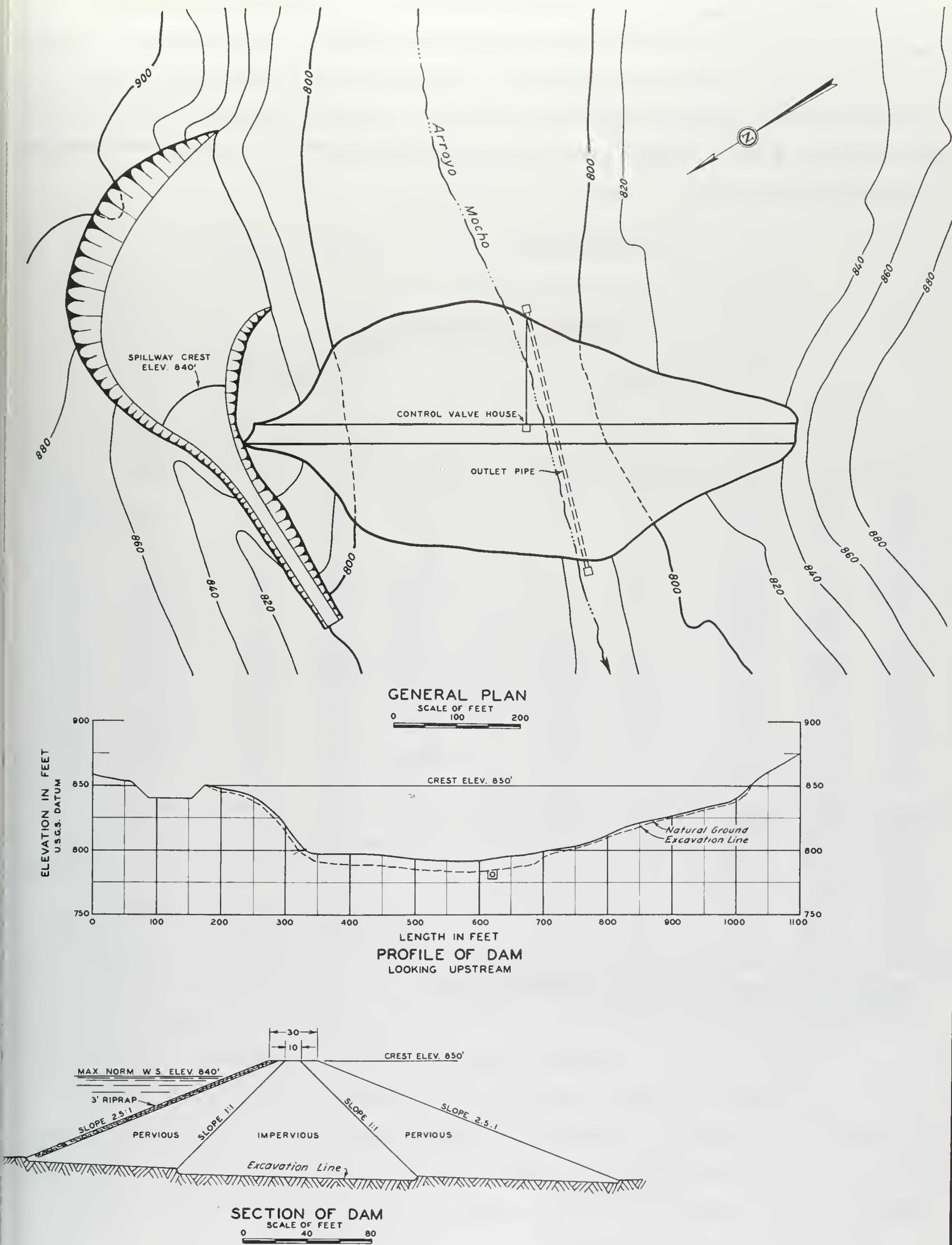


Figure 5. PRINCIPAL FEATURES OF PROPOSED MOCHO DAM

With a spillway crest elevation of 840 feet, a reservoir with a capacity of about 2,000 acre-feet and an estimated annual safe yield of 3,100 acre-feet would be created. About 1,400 acre-feet would be new yield and is based on conjunctive operation with the downstream ground water basin. An annual summary of the monthly yield study for Mocho Reservoir, operated conjunctively with the ground water storage in the Livermore Valley, is presented as Table 35.

TABLE 35

YEARLY SUMMARY OF MONTHLY YIELD STUDY OF
MOCHO RESERVOIR ON ARROYO MOCHO,
OPERATED IN CONJUNCTION WITH GROUND WATER STORAGE

Storage capacity: 2,000 acre-feet

Safe annual yield: 3,100 acre-feet*

(In acre-feet)

Water Year	Inflow	Release	Maximum Storage	Spill	Water Year	Inflow	Release	Maximum Storage	Spill
1894-95	11,900	7,400	2,000	4,500	1924-25	490	490	0	0
95-96	3,300	3,300	0	0	25-26	2,430	2,430	0	0
96-97	7,900	7,180	2,000	720	26-27	3,190	3,190	0	0
97-98	0	0	0	0	27-28	1,270	1,270	0	0
98-99	1,400	1,400	0	0	28-29	360	360	0	0
1899-1900	1,000	1,000	0	0	1929-30	1,600	1,600	0	0
00-01	3,700	3,700	50	0	30-31	900	900	0	0
01-02	2,300	2,300	0	0	31-32	4,500	4,500	450	0
02-03	3,500	3,500	0	0	32-33	800	800	0	0
03-04	3,100	3,100	0	0	33-34	600	600	0	0
1904-05	1,200	1,200	0	0	1934-35	1,800	1,800	0	0
05-06	10,900	7,400	2,000	3,500	35-36	3,900	3,900	150	0
06-07	18,800	7,400	2,000	11,400	36-37	4,800	4,800	600	0
07-08	1,200	1,200	0	0	37-38	12,000	7,400	2,000	4,600
08-09	11,500	7,400	2,000	4,100	38-39	500	500	0	0
1909-10	2,600	2,600	0	0	1939-40	5,500	5,500	950	0
10-11	10,900	7,400	2,000	6,900	40-41	9,500	7,400	2,000	2,100
11-12	18,800	410	0	0	41-42	5,900	5,900	1,150	0
12-13	1,200	260	0	0	42-43	3,500	3,500	0	0
13-14	11,500	6,100	1,800	5,000	43-44	2,000	2,000	0	0
1914-15	8,350	6,600	2,000	1,750	1944-45	3,000	3,000	0	0
15-16	11,800	7,460	2,000	4,340	45-46	900	900	0	0
16-17	2,920	2,920	380	0	46-47	300	300	0	0
17-18	510	510	0	0					
18-19	3,120	3,120	0	0					
1919-20	980	980	0	0					
20-21	1,670	1,670	0	0					
21-22	4,780	4,780	1,590	0					
22-23	1,420	1,420	0	0	MEAN	4,000	3,100		900
23-24	30	30	0	0					

* Evaporation would be minor since the reservoir would generally be emptied by May 30th, and will remain empty until after September 30th.

The reservoir area is sparsely covered by trees and light brush, and is presently used for grazing. Improvements within the area consist of several small ranch buildings, a county road, and a power transmission line. The road and the power line would each require about 1.2 miles of relocation. General features of the proposed Mocho Dam are presented in Table 36.

TABLE 36

GENERAL FEATURES OF MOCHO DAM AND RESERVOIR

Earthfill Dam	
Crest elevation, in feet	850
Crest length, in feet	825
Crest width, in feet	30
Side slopes	2.5:1
Elevation of stream bed, in feet	785
Height, spillway lip above stream bed, in feet	55
Freeboard above spillway lip, in feet	10
Volume of fill, in cubic yards	236,000
Reservoir	
Surface area at spillway lip, in acres	83
Capacity at spillway lip, in acre-feet	2,000
Drainage area, in square miles	39
Estimated mean annual runoff, in acre-feet	4,000
Estimated annual safe yield, in acre-feet	3,100
Estimated annual new yield, in acre-feet	1,400
Type of spillway--chute with curved ogee weir, concrete-lined spillway capacity, in second-feet	7,000
Type of outlet--30-inch diameter steel pipe beneath abutment	

The capital cost of Mocho Dam and Reservoir is estimated to be about $886,000 ased upon construction costs prevailing in 1962. The annual cost of the project is stimated at $45,500. The resultant estimated average unit cost of the 1,400 acre-eet of new water per season then would be nearly $33.00 per acre-foot.

Design of features of Mocho Dam and Reservoir was necessarily of a preliminary ature, and was primarily for cost estimating purposes. More detailed investigation, hich would be required to prepare construction plans and specifications, might esult in a design differing in detail from that presented in this bulletin.

Capital costs were estimated from preliminary designs, based on data from revious surveys and from surveys made during the current investigation. Unit prices r construction items were determined from bid data on projects similar to those under onsideration or from manufacturers' cost lists. Estimates of capital costs included he costs of rights-of-way and construction, plus 10 percent for administration and ngineering and 15 percent for contingencies. Estimates of annual costs include interest on the capital investment at 4 percent with repayment over a 40-year period, replacement, operation, and maintenance costs. The interest rate and repayment period were selected on the premise that Alameda County Flood Control and Water Conservation District, which has obtained a water rights permit, would be the construction agency.

San Antonio Dam and Reservoir

The 1961 water supply improvement bond issue of the City and County of San Francisco, voted favorably on November 7, 1961, included $6.5 million dollars for San Antonio Dam and Reservoir on La Costa Creek, with a capacity of 51,000 acre-feet. The city has owned this site, and a large portion of the tributary watershed, for many years, and intends to utilize it within a few years.

The city intends to operate San Antonio Dam and Reservoir for both conservation of water from San Antonio Creek and regulation of water from the Hetch-Hetchy Aqueduct. A connecting pipeline will be constructed from this reservoir to the Hetch-Hetchy Aqueduct. Since the City of San Francisco is developing this watershed, it is anticipated that none of the newly developed water from this project will be available for use outside the city's service area. The structure on San Antonio Creek will be an earthfill dam about 180 feet high, about three miles east of Sunol. Final design is currently in progress on this project.

Plans for Importation of Water

As stated in the Department of Water Resources' Bulletin No. 3,

> "The objectives of The California Water Plan in the San Francisco Bay Area are twofold: First, the development of local water resources to the maximum practicable extent to satisfy increasing needs for irrigation, urban, industrial, and recreational purposes, and a measure of flood control; and second, the importation of water through facilities of The California Aqueduct System to meet the ultimate requirements of all lands considered susceptible of water service. Because of the limited potential for further development of local water resources, elimination of present water problems and provision of water to meet future increased requirements in the area will necessitate substantial importation of water from areas of surplus in other regions of the state. In this regard, additional imports proposed by certain water service agencies, notably the City of San Francisco and the East Bay Municipal Utility District, by extension and enlargement of their existing facilities, have been taken into consideration in the formation of plans for ultimate water supply in the area."

Data and estimates presented in Chapter III have shown that the requirement for supplemental water in the Alameda County Area, without allowance for supplies available from the South Bay Aqueduct, will be about 82,000 acre-feet per season in the year 1990. The need will be about 270,000 acre-feet and 325,000 acre-feet per season, respectively, without and with the development of the salt ponds and marshlands, under probable ultimate development. Therefore, it is apparent that the solution to future water problems in southern Alameda County will involve the development of an imported supply.

With the start of construction of the South Bay Aqueduct in November 1959, a major step toward solving future water supply problems in Alameda County was undertaken.

South Bay Aqueduct

The South Bay Aqueduct is an integral part of the State Water Facilities, and its purpose is to provide supplemental water to the counties lying south of San Francisco Bay. The portion of the aqueduct already constructed begins west of the City of Tracy, proceeds southwesterly through the Coast Range over Altamont Pass into Livermore Valley. Construction is under way to continue the aqueduct along the foothills southwesterly to Mission San Jose, which is southwest of Niles. It will finally terminate at Airpoint Reservoir northeast of San Jose near the City of Milpitas in Santa Clara County. The alignment and main features of the South Bay Aqueduct are delineated on Plate 4.

Initially, water for the aqueduct is being diverted from the Delta-Mendota Canal through an interim canal and pumping plant which raises the water about 50 feet into Bethany Forebay. Pumps at the South Bay Pumping Plant lift water about 600 feet from elevation 240 in the Bethany Forebay. When the Delta Pumping Plant and the North San Joaquin Division (the reach from the Delta to San Luis Reservoir) of the California Aqueduct is constructed, water for the South Bay Aqueduct will be obtained directly through the State Water Facilities.

The Interim Intake Canal and Pumping Plant, South Bay Pumping Plant and Discharge Line, and the several features from the surge tank through Patterson Reservoir, taken collectively, constitute the Livermore Valley Division.

The Interim Intake Canal is a temporary, unlined canal about two miles long with a capacity of 150 second-feet. Water is conveyed from the Delta-Mendota Canal via the intake canal and pumped into Bethany Forebay by the Intake Pumping Plant which is a temporary, outdoor plant which will have five 30-second-foot pumping units, and is located at the base of Bethany Dam. Two of the five pumps are presently installed.

Bethany Forebay Dam is an 80-foot high earthfill structure with a crest length of about 700 feet at an elevation of 250 feet. The reservoir has a gross capacity of 900 acre-feet and an operating capacity of about 375 acre-feet.

Construction costs for the Interim Intake Canal, Intake Pumping Plant, and Bethany Forebay Reservoir totalled $872,000.

The South Bay Pumping Plant lifts water approximately 600 feet from Bethany Forebay into a 54-inch steel discharge line to a surge tank. The surge tank consists of a 54-inch steel standpipe 66 feet high, enclosed within a 13-foot diameter steel pipe 87 feet high. The design capacity of the pumping plant and the initial


SOUTH BAY PUMPING PLANT

discharge line is 120 second-feet. The initial pumping installation, however, consists of one 15 second-foot and one 30 second-foot pumping units. Construction costs of the surge tank, discharge line and pumping plant total about $820,000.

The Brushy Creek Pipeline, the Dyer Canal, the Altamont Pipeline, and a portion of the Livermore Valley Canal carry water from the surge tank to Patterson Reservoir. The Brushy Creek pipeline is a 54-inch concrete pipe about 2½ miles in length, with a capacity of 120 second-feet. The concrete lined Dyer Canal is about two miles long, has a bottom width of eight feet, and is designed to carry 300 second-feet. The Altamont Pipeline is a 72-inch diameter reinforced concrete pipe about 2 1/4 miles long with a capacity of 300 second-feet. A two-mile portion of the Livermore Valley Canal, with the same dimensions and capacity as the Dyer Canal, completes the initial phase of the South Bay Aqueduct with delivery of water to Patterson Reservoir, which is formed by a 30-foot high dam and impounds about 100 acre-feet. Construction costs for the two pipelines, two canals, and Patterson Reservoir total about $3,115,000.

The Doolan Division of the South Bay Aqueduct consists of a branch to serve northern Livermore Valley. It will branch out of the Altamont Pipeline of the Livermore Division and will extend about 12 miles in a north-westerly direction to terminate at Doolan Dam and Reservoir. Under the studies made by the Department of Water Resources the Doolan Branch has been tentatively sized to deliver 17,000 acre-feet on demand for a maximum capacity of 63 second-feet. Doolan Reservoir, under these studies, would contain about 100 acre-feet of emergency supply. Other studies had been based upon consideration of a larger regulatory storage reservoir with capacity of up to 5,000 acre-feet. Definite reservoir sizing will depend upon water contractees' needs and final design.

The Alameda Division of the South Bay Aqueduct will consist of eight miles of Alameda Canal and the portion of the Del Valle siphon between the end of Alameda Canal and the Del Valle Branch turnout.

The Del Valle Branch will consist of the Del Valle Branch pipeline, which is about 2 miles long, the Del Valle Pumping Plant, and Del Valle Dam and Reservoir, which will have a capacity of 74,000 acre-feet and a water surface area of approximately 1,000 acres. The dam and reservoir will be located on the Arroyo del Valle about 6 miles south of the City of Livermore and will be used primarily for flood control, recreation, and regulation.

The Niles Division will extend from the Del Valle Branch turnout to the Alameda Bayside turnout near Mission San Jose and will consist of the following features: the remaining portion of the Del Valle siphon, including the South Livermore turnout; the La Costa Tunnel, a horseshoe-shaped, concrete-lined tunnel about a mile long; Sunol siphon, a concrete pipe approximately seven miles long and includes the Vallecitos turnout; Mission Tunnel, a horseshoe-shaped, concrete-lined tunnel approximately 0.8 mile long, through Mission Pass; and Mission Pipeline, a concrete pipe about one-half mile long.

The Santa Clara Division will consist of the Santa Clara pipeline, extending southerly some 9.0 miles along the north-eastern edge of the Santa Clara Valley, terminating at the proposed Airpoint Reservoir. Airpoint Reservoir would have a capacity of 3,500 acre-feet and a water surface area of approximately 65 acres. It would be located immediately east of the City of Milpitas and would be formed by Airpoint Dam, an earthfill structure approximately 190 feet high. It would serve as the terminal reservoir of the South Bay Aqueduct and would also serve as a recreational facility.

The portion of the aqueduct from Del Valle Branch turnout to South Livermore turnout will be constructed to a capacity of 363 second-feet, the portion from South Livermore turnout to Vallecitos turnout to 305 second-feet, the portion from Vallecitos turnout to Alameda Bayside turnout to 255 second-feet, and the portion from Alameda Bayside turnout to Airpoint Reservoir will be constructed to a capacity of 186 second-feet.

In the future, as the demand for water increases, the South Bay Pumping Plant discharge line, surge tank, and the Brushy Creek Pipeline will be increased to the 300 second-foot capacity for which the South Bay Aqueduct is designed.

On May 10, 1962, the first stage of the South Bay Aqueduct and the new water treatment plant of the Alameda County Flood Control and Water Conservation District, Zone No. 7 were dedicated. This water treatment plant, located near Patterson Reservoir, was designed to treat six million gallons per day, initially, with expected expansion to 30 million gallons per day as the demand develops. The land acquisition and construction costs for the initial installation were about $800,000. When demand for water in the Alameda County Area increases beyond the 300 second-foot design capacity of the aqueduct, it is considered probable that a parallel facility will be constructed to satisfy that demand.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As a result of field investigation and analysis of available data on the water resources and water problems of the Alameda County Area, and on the basis of the estimates and assumptions previously discussed, the following conclusions and recommendations are made:

Conclusions

1. The present basic water problem in the Alameda County Area is perennial overdraft on the ground water resources of the Bay Plain. This overdraft has resulted in a lowering of ground water levels in the principal pumping aquifers in the Bay Plain to depths below sea level, with resultant intrusion of sea water from San Francisco Bay. Ground water in the upper aquifer and in portions of the lower aquifer in the Niles Cone area have been degraded by this sea-water intrusion. In addition, there exists the threat of direct intrusion of sea water into the lower aquifer from underneath the bay by reason of the perennial landward gradient in that aquifer from the direction of the bay.

2. There is a similar overdraft problem in the general lowering of the ground water levels in the Livermore Valley. This presents a threat of degradation of the quality of the ground water by increasing the concentration of boron.

3. The estimated annual safe yield of the ground water basins of the Alameda County Area is about 44,000 acre-feet, distributed as follows: Livermore Valley, 17,000 acre-feet; and Bay Plain, 27,000 acre-feet.

4. The present (1951) mean annual requirement for supplemental water in the Alameda County Area is about 20,200 acre-feet, distributed as follows: Livermore Valley Unit, 3,700 acre-feet; and Southern Alameda Unit, 16,500 acre-feet. It is probable that all of the future supplemental water requirements of the portion of the Southern Alameda Unit lying north of the northern boundary of the Alameda County Water District will be served from existing and proposed facilities of the East Bay Municipal Utility District and the San Francisco Water Department. Accordingly, the forecast future requirement for supplemental water in the Alameda County Area does not include that portion of the Southern Alameda Unit.

5. The estimated mean annual requirement for supplemental water in the Alameda County Area in the year 1990 will be about 82,000 acre-feet, distributed as follows: Livermore Valley and Sunol Valley Units, 45,000 acre-feet; and Southern Alameda Unit, 37,000 acre-feet. Recent studies by the Alameda County Water District, based on greater demands and less local supply, indicate correspondingly greater supplemental water requirements.

6. Under forecast ultimate conditions of development in the Alameda County Area, the mean annual requirement for supplemental water will be about 270,000 acre-feet without, and 325,000 acre-feet with, the development of the salt ponds and marshlands lying between the Southern Alameda Unit and the bay. This will be distributed as follows: Livermore Valley and Sunol Valley Units, 190,000 acre-feet; and Southern Alameda Unit, 80,000 acre-feet without, and 135,000 acre-feet with, the development of the salt ponds and marshlands.

7. Satisfaction of the probable ultimate requirement for supplemental water in the Alameda County Area will require additional importation of water.

8. Surface and ground water supplies of the Alameda County Area generally are of good mineral quality and are suitable for most beneficial uses, except for:

a. The presence of high boron concentration in wells located in the eastern portion of Livermore Valley.

b. Degradation by intrusion of sea water into the ground water of the upper aquifer and certain portions of the lower aquifer in the Niles Cone area of the Bay Plain.

9. At present (1951), approximately 80,000 acre-feet of water wastes to San Francisco Bay annually. Construction of San Antonio Reservoir and Del Valle Reservoir will salvage a portion of this runoff. Lack of suitable reservoir sites on the many small streams involved and the high cost of development will limit the amount of additional runoff which can be economically salvaged.

10. Some local runoff can be developed from the proposed Del Valle Dam and Reservoir of the South Bay Aqueduct. The amount which can be developed and the cost thereof is currently (June 1962) under study by the Department of Water Resources the Pleasanton Township County Water District, and the Alameda County Water District.

11. Mocho Dam and Reservoir could be developed and operated in conjunction with the ground water basin in Livermore Valley to provide an estimated average new yield of 1,400 acre-feet annually. The estimated capital cost would be about $886,000 and the average cost of water would be nearly $33.00 per acre-foot.

12. The City of San Francisco will develop the San Antonio Creek watershed for conservation purposes by the construction of a dam on San Antonio Creek, about one mile upstream from its confluence with Alameda Creek.

13. Supplemental water for the Alameda County Area will be met largely by importation via the South Bay Aqueduct of the State Water Facilities. Water will be delivered to the area at an estimated cost, canalside, of about $24.00 per acre-foot.

14. The rate of intrusion of sea water into the aquifers of the Bay Plain must be arrested as quickly as possible to avoid further loss of the utility of this valuable natural storage capacity. This can be accomplished by gradually reducing the rate of ground water extraction as agricultural areas are urbanized and supplied through surface delivery systems. Control of sea-water intrusion could be accelerated by securing the maximum possible amount of water from the South Bay Aqueduct available to the Alameda County Water District for replenishment of the ground water basin.

15. There is an additional water problem manifested by periodic occurrence of heavy winter and spring storms with resultant uncontrolled flood flows that cause damage in the western portion of Livermore Valley, in Niles Canyon, and along the lower reaches of Alameda Creek in the Bay Plain. The proposed flood control project of the Corps of Engineers, consisting of 35,000 acre-feet of flood control storage in Del Valle Reservoir and about 12 miles of channel improvement on the Bay Plain, would provide protection on the Bay Plain, in Niles Canyon and along Arroyo del Valle. However, in its review of the Corps of Engineers report the Department of Water Resources concluded that future channel improvements will be needed in the Livermore Valley.

Recommendations

It is recommended that:

1. The programs of hydrologic investigation by local agencies be continued for the purpose of maintaining adequate and current evaluation of the water problems caused by the continuing growth and development of the Alameda County Area.

2. The maximum amount of water which the Alameda County Water District can arrange to purchase should be obtained from the South Bay Aqueduct, to alleviate the sea water intrusion problem.

APPENDIX A

AGREEMENTS, AND THEIR SUPPLEMENTS,
BETWEEN THE STATE OF CALIFORNIA,
THROUGH ITS VARIOUS AGENCIES,
AND THE COUNTY OF ALAMEDA

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AGREEMENTS, AND THEIR SUPPLEMENTS,
BETWEEN THE STATE OF CALIFORNIA,
THROUGH ITS VARIOUS AGENCIES,
AND THE COUNTY OF ALAMEDA

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,
THE COUNTY OF ALAMEDA
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quadruplicate, entered into by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Alameda, hereinafter referred to as the "County"; and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H :

WHEREAS, by The State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, State agency or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money in behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, the County desires and hereby requests the Board to enter into a cooperative agreement for the making of an investigation and report on the underground water supply in Livermore Valley, which embraces all the drainage area tributary to Arroyo de la Laguna above the confluence of Vallecitos Creek near Sunol within the Murray and Pleasanton Townships, in the County of Alameda, including quality, replenishment and utilization thereof, and if possible, a method or methods of solving the water problems involved; and

WHEREAS, the Board hereby requests the State Engineer to cooperate in making an investigation and report on the underground water supply in said Livermore Valley, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the water problems involved;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of investigation and report on the underground water supply in Livermore Valley, in the County of Alameda, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the water problems involved.

The Board by this agreement authorizes and directs the State Engineer to cooperate by making said investigation and report and by otherwise advising and assisting in making an evaluation of present and ultimate underground water problems in said Livermore Valley, and in formulating a solution or solutions of the water problems thereof.

During the progress of said investigation and report all maps, plans, information, data and records pertaining thereto which are in the possession of any party hereto shall be made fully available to any other party for the due and proper accomplishment of the purposes and objects hereof.

The work under this agreement shall be diligently prosecuted with the objective of completion of the investigation and report on or before July 1, 1950, or as nearly thereafter as possible.

ARTICLE II - FUNDS:

The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Five Thousand Dollars ($5,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also, upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Five Thousand Dollars ($5,000) from funds appropriated to the Board by Item 335 of the Budget Act of 1948, for expenditure by the State Engineer in performance of the work provided for in this agreement and the State Controller will be requested to make such transfer.

If the Director of Finance, within thirty (30) days after receipt by the State Engineer of said Five Thousand Dollars ($5,000) from the County, shall not have approved the deposit thereof into said Water Resources Revolving Fund, together with the transfer of the sum of Five Thousand Dollars ($5,000) from funds appropriated to the Board by Item 335 of the Budget Act of 1948, for expenditure by the State Engineer in performance of the work provided for in this agreement, said sum contributed by the County shall be returned thereto by the State Engineer.

It is understood by and between the parties hereto that the sum of Ten Thousand Dollars ($10,000) to be made available as hereinbefore provided is adequate to perform approximately half of the above specified work and it is the understanding that either the County or an appropriate local agency will make a further sum of Four Thousand Five Hundred Dollars ($4,500) available at the commencement of the second year of said investigation which will be subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the sum of Ten Thousand Dollars ($10,000) as made available hereunder and when said sum is exhausted, the Board and the State Engineer may discontinue the work provided for in this agreement and shall not be liable or responsible for the resumption and completion thereof until further sums as specified in the preceding paragraph are made available.

Upon completion of and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to said Board, and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board, and to the County, in equal amount.

ARTICLE III - EFFECTIVE DATE

This agreement shall become effective on July 1, 1948, or upon its execution by all the parties hereto, whichever is the later date.

IN WITNESS WHEREOF, the parties hereunto have affixed their signatures, the County of Alameda on the 31st day of August, 1948, the Board on the 13th day of September, 1948, and the State Engineer on the 17th day of September, 1948.

COUNTY OF ALAMEDA

By /s/ HARRY BARTELL
Chairman, Board of Supervisors

/s/ G. E. WADE
Clerk, Board of Supervisors

/s/By L. F. GROOGAN

Approval Recommended:

/s/ SPENCER BURROUGHS
Principal Attorney
Division of Water Resources

Approved as to Form:

/s/ J. F. COAKLEY
District Attorney
County of Alameda

By /s/ Douglas R. Dunning
Deputy

STATE WATER RESOURCES BOARD

By /s/ C. A. GRIFFITH
Vice-Chairman

Approved:

/s/ JAMES S. DEAN
Director of Finance

Approved as to Legality:

/s/ C. C. CARLETON
Chief Attorney
Department of Public Works

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

C. H. PURCELL

By /s/ C. H. PURCELL
Director of Public Works

/s/ EDWARD HYATT
Edward Hyatt
State Engineer

RS Form	J.W.M. Budget	Value	Description

DEPARTMENT OF FINANCE

A P P R O V E D

Sep 27 1948

~~JAMES S. DEAN, Director~~

~~By Administrative Adviser~~

SUPPLEMENTAL AGREEMENT
BETWEEN
THE STATE WATER RESOURCES BOARD,
THE COUNTY OF ALAMEDA, AND THE
DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Alameda, hereinafter referred to as the "County"; and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H :

WHEREAS, by agreement heretofore entered into by and between the County of Alameda, the Board and the State Engineer, executed by the County on the 31st day of August, 1948, by the Board on the 13th day of September, 1948, and by the State Engineer on the 17th day of September, 1948, the making by the State Engineer of an investigation and report on the underground water supply in Livermore Valley which embraces all the drainage area tributary to Arroyo de la Laguna above the confluence of Vallecitos Creek near Sunol within the Murray and Pleasanton Townships, in the County of Alameda, including quality, replenishment and utilization thereof, and if possible, a method or methods of solving the water problem involved, was provided for; and

WHEREAS, under said agreement the County made available the sum of Five Thousand Dollars ($5,000) which was matched in an equal amount by the Board for expenditure by the State Engineer in the performance of the work provided for in said agreement; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the second year of said investigation the County would make available a further sum of Four Thousand Five Hundred Dollars ($4,500) subject to a matching or contribution in equal amount by the Board for the completion of said investigation and report; and

WHEREAS, the funds provided for under said prior agreement, to which this agreement is supplemental, have been exhausted and additional funds are now required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Nine Thousand Dollars ($9,000) shall be provided, Four Thousand Five Hundred Dollars ($4,500) by the County, and Four Thousand Five Hundred Dollars ($4,500) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Four Thousand Five Hundred Dollars ($4,500) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Four Thousand Five Hundred Dollars ($4,500) from funds appropriated to the Board by Item 259 of the Budget Act of 1949 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Nineteen Thousand Dollars ($19,000) as made available under said prior agreement and this supplemental agreement and if funds are exhausted before completion of said work the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the completion thereof.

4. In so far as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

IN WITNESS WHEREOF, the parties hereunto have affixed their signatures, the County on the 29th day of September, 1949, the Board on the 14th day of October, 1949, and the State Engineer on the 15th day of October, 1949.

COUNTY OF ALAMEDA

Approved as to form:

J. F. Coakley, District Attorney

by /s/ DOUGLAS R. DUNNING
Deputy District Attorney

District Attorney, County of Alameda

By /s/ HARRY BARTELL
Chairman, Board of Supervisors

S E A L Board of Supervisors
Alameda County

/s/ G. E. WADE
Clerk, Board of Supervisors

Approval Recommended:

/s/ HENRY HOLSINGER
Principal Attorney
Division of Water Resources

Approval Recommended:

/s/ C. R. MONTGOMERY
Chief Attorney
Department of Public Works

Approved:

Director of Finance

STATE WATER RESOURCES BOARD

By /s/ C. A. GRIFFITH
Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

C. H. PURCELL
Director of Public Works

S E A L

By /s/ FRANK B. DURKEE
Deputy Director

/s/ EDWARD HYATT
Edward Hyatt
State Engineer

L.D.K.: Form	F.J.M.: Budget	Value	Descript.

DEPARTMENT OF FINANCE
A P P R O V E D

OCT 21 1949

JAMES S. DEAN, Director

By /s/ LOUIS J. HEINZER
Administrator Adviser

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,
THE COUNTY OF ALAMEDA
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quadruplicate, entered into as of December 1, 1949, by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Alameda, hereinafter referred to as the "County"; and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H :

WHEREAS, by The State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, State agency or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money in behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, the County desires and hereby requests the Board to enter into a cooperative agreement for the making of an investigation and report on the ground water resources in southern Alameda County, which embraces all the drainage area tributary to San Francisco Bay within the County between San Leandro Creek and Coyote River except that tributary to Arroyo de la Laguna above the confluence of Vallecitos Creek near Sunol, including location, replenishment, quality and utilization thereof, and if possible, a method or methods of solving the water problems involved;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of an investigation and report on the ground water supply in southern Alameda County, including location, replenishment, quality and utilization thereof, and, if possible, a method or methods of solving the water problems involved.

The Board by this agreement authorizes and directs the State Engineer to cooperate by making said investigation and report and by otherwise advising and assisting in making an evaluation of present and ultimate ground water problems in said southern Alameda County, and in formulating a possible solution of the water problems thereof.

During the progress of said investigation and report all maps, plans, information, data and records pertaining thereto which are in the possession of any party hereto shall be made fully available to any other party for the due and proper accomplishment of the purposes and objects hereof.

The work under this agreement shall be diligently prosecuted with the objective of completion of the investigation and report on or before December 31, 1951, or as nearly thereafter as possible.

ARTICLE II - FUNDS

The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Ten Thousand Dollars ($10,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also, upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Ten Thousand Dollars ($10,000) from funds made available to the Board by Item 259 of the Budget Act of 1949 as augmented, for expenditure by the State Engineer in performance of the work provided for in this agreement and the State Controller will be requested to make such transfer.

If the Director of Finance, within thirty (30) days after receipt by the State Engineer of said Ten Thousand Dollars ($10,000) from the County, shall not have approved the deposit thereof into said Water Resources Revolving Fund, together with the transfer of the sum of said Ten Thousand Dollars ($10,000) from funds made available to the Board, for expenditure by the State Engineer in performance of the work provided for in this agreement, said sum contributed by the County shall be returned thereto by the State Engineer.

It is understood by and between the parties hereto that the sum of Twenty Thousand Dollars ($20,000) to be made available as hereinbefore provided is adequate to perform approximately forty per cent of the above specified work and it is the understanding that either the County or an appropriate local agency will make a further sum of Fifteen Thousand Dollars ($15,000) available at the commencement of the second year of said investigation which will be subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the sum of Twenty Thousand Dollars ($20,000) as made available hereunder and when said sum is exhausted, the Board and the State Engineer may discontinue the work provided for in this agreement and shall not be liable or responsible for the resumption and completion thereof until further sums as specified in the preceding paragraph are made available.

Upon completion of and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to said Board, and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board, and to the County, in equal amount.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to form:

J. F. Coakley, District Attorney

By /s/ DOUGLAS R. DUNNING
Deputy District Attorney
County of Alameda

Approval Recommended:

/s/ HENRY HOLSINGER
Principal Attorney
Division of Water Resources

Approved as to Legality:

/s/ C.R. MONTGOMERY
Chief Attorney
Department of Public Works

Approved:

Director of Finance

: E.J.R.:F.J.M.: : :
: Form :Budget:Value: Descript. :
: DEPARTMENT OF FINANCE :
: APPROVED :
: Jan 19 1950 :
: James S. Dean, Director :
: By /s/ LOUIS J. HEINZER :
: Administrative Adviser :

COUNTY OF ALAMEDA

By /s/ HARRY BARTELL
Chairman, Board of Supervisors

/s/ HAROLD SCHULZE
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ C. A. GRIFFITH
Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA S
E
C. H. PURCELL A
By /s/ C. H. PURCELL L
Director of Public Works

EDWARD HYATT
Edward Hyatt
State Engineer

By /s/ A. D. EDMONSTON
A. D. Edmonston
Assistant State Engineer

SUPPLEMENTAL
AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,
THE COUNTY OF ALAMEDA
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quadruplicate, entered into as of December 1, 1950, by the State Water Resources Board, hereinafter referred to as the "Board"; the County of Alameda, hereinafter referred to as the "County"; and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H :

WHEREAS, by agreement heretofore entered into as of December 1, 1949, by and between the County, the Board and the State Engineer, it was provided that the work to be performed thereunder shall consist of the making by the State Engineer of an investigation and report on the ground water resources in southern Alameda County, which embraces all the drainage area tributary to San Francisco Bay within the County between San Leandro Creek and Coyote River except that tributary to Arroyo de la Laguna above the confluence of Vallecitos Creek near Sunol, including location, replenishment, quality and utilization thereof, and if possible, a method or methods of solving the water problems involved; and

WHEREAS, under said agreement the County made available the sum of Ten Thousand Dollars ($10,000) which was matched in an equal amount by the Board for expenditure by the State Engineer in the performance of the work provided for in said agreement; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the second year of said investigation the County or an appropriate local agency would make available a further sum of Fifteen Thousand Dollars ($15,000) subject to a matching or contribution in equal amount by the Board for the completion of said investigation and report; and

WHEREAS, the funds provided for under said prior agreement, to which this agreement is supplemental, have been exhausted and additional funds are now required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Thirty Thousand Dollars ($30,000) shall be provided, Fifteen Thousand Dollars ($15,000) by the County, and Fifteen Thousand Dollars ($15,000) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Fifteen Thousand Dollars ($15,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Fifteen Thousand Dollars ($15,000) from funds appropriated to the Board by Item 257 of the Budget Act of 1950 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Fifty Thousand Dollars ($50,000) as made available under said prior agreement and this supplemental agreement and if funds are exhausted before completion of said work the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the completion thereof.

4. In so far as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified and continued in effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinabove first written.

Approved as to form:

J. F. Coakley, District Attorney

By /s/ DOUGLAS R. DUNNING
Deputy District Attorney

District Attorney
County of Alameda

Approval Recommended:

/s/ HENRY HOLSINGER
Principal Attorney
Division of Water Resources

COUNTY OF ALAMEDA

SEAL

By /s/ HARRY BARTEL
Chairman, Board of Supervisors

/s/ G. E. WADE
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

/s/ C. A. GRIFFITH
Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

Approval Recommended:

C. H. PURCELL S E A L
Director of Public Works

/s/ ROBERT E. REED
Chief Attorney
Department of Public Works

By /s/ FRANK B. DURKEE
Deputy Director

Approved as to
Number and Funds

Original signed by E. R. Higgins
Comptroller

/s/ A. D. EDMONSTON
A. D. Edmonston
State Engineer

Approved:

/s/ JAMES S. DEAN
Director of Finance

A.J.R.	F.J.M.		
Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
A P P R O V E D
Dec 29 1950

Agreement No. 251274

COOPERATIVE AGREEMENT
BETWEEN THE STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
AND THE ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

This agreement, made and entered into as of the 10th day of January, 1961, by and between the State of California, acting by and through its Department of Water Resources, hereinafter referred to as the "State", and the Alameda County Flood Control and Water Conservation District, hereinafter referred to as the "District":

WITNESSETH

WHEREAS, the State in cooperation with Alameda County has made an investigation of the Alameda County area pursuant to authority under Articles 4 and 5, Chapter 1, Part 6, Division 6 of the California Water Code; and

WHEREAS, the results of this investigation were published in July 1955 in a preliminary edition of Bulletin No. 13, entitled "Alameda County Investigation"; and

WHEREAS, a joint public hearing was held on the preliminary edition of Bulletin No. 13 by the State Water Resources Board and the State (Department of Water Resources); and

WHEREAS, the State received comments on the preliminary edition of Bulletin No. 13 from individuals and agencies; and

WHEREAS, the District has and is assuming the functions of the County of Alameda in water resources planning and has requested the State to bring the preliminary edition of the bulletin up-to-date and to publish the final edition of Bulletin No. 13;

NOW, THEREFORE, it is mutually agreed, subject to the availability of funds, as follows:

(1) The State shall revise the preliminary edition of Bulletin No. 13 as described in the attached sheet, incorporated herein, entitled "Work Program" and marked "Exhibit A", and shall print and publish the final edition of the bulletin.

(2) The cost of accomplishing the work program is estimated to be $10,000 to be shared equally by the District and the State. The District shall contribute $5,000 which shall be transmitted to the State prior to the commencement of the work. The State shall contribute $5,000 from funds appropriated to the Department of Water Resources by Item 256 of the Budget Act of 1960.

(3) Funds contributed by the parties shall be deposited in the Water Resources Revolving Fund in the State Treasury for expenditures by the State in performance of the work provided for in this agreement.

(4) Neither the State or the District shall under any circumstances be obligated to expend any amount in excess of the funds made available hereunder for work provided for under this agreement.

(5) Upon completion of the work provided for in this agreement, the State shall furnish to the District a statement of expenditures made under this agreement. Any unexpended balance of the $10,000 referred to above shall be returned to the State and to the District in equal amounts.

(6) The work done under this agreement shall be diligently prosecuted with the objective of publishing Bulletin No. 13 by June 30, 1961, or as nearly thereafter as possible.

Approved as to Form
and Procedure

/s/ J. F. COAKLEY
District Attorney, County of Alameda

/s/ by D. R. DUNNING
Assistant

Approved as to Form
and Procedure

/s/ MARK C. NOSLER (Acting)
Chief Counsel, Department of Water
Resources

Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
A P P R O V E D
Mar 1 1961

JOHN E. CARR, Director

By /s/ EMIL J. RELAT
Senior Counsel

Alameda County Flood Control and Water
Conservation District

By /s/ EMANUEL P. RAZETO
Chairman, Board of Supervisors

ATTEST:

JACK G. BLUE
County Clerk of the County of
Alameda and ex-officio Clerk of
the Board of Supervisors of the
Alameda County Flood Control and
Water Conservation District

State of California Department of Water
Resources

Director of Water Resources

By /s/ PAUL L. BARNES
Paul L. Barnes
Division of Administration

COOPERATIVE AGREEMENT BETWEEN
THE STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
AND THE ALAMEDA COUNTY FLOOD CONTROL
AND WATER CONSERVATION DISTRICT

EXHIBIT A

WORK PROGRAM

It is estimated that the work will be completed in one year. The general work program will be to revise and publish Bulletin No. 13. The specific work program will include:

1. Minor revisions to Chapter I, "Introduction" and Chapter II, "Water Supply," to ensure consistency with 1960 development and to bring up to date with more recent information and investigations by State and local agencies.

2. Extensive revisions to Chapter III, "Water Utilization and Supplementa Requirements," to reflect 1960 populations and unit use of water.

3. Extensive revisions to Chapter IV, "Plans for Water Development", to eliminate obsolete projects and to bring other projects up to date.

4. Revisions to Appendix D, "Applications to Appropriate Water in Alameda County Area", to reflect applications as of 1960.

5. Compilation of Appendix H, "Comments of Interested Agencies and Individuals on the Alameda County Investigation".

6. Revise the map of water service agencies in Alameda County to show Alameda County Flood Control and Water Conservation District, Zone No. 7.

7. Such other revisions as the Department of Water Resources deems appropriate.

APPENDIX B

RECORDED AND ESTIMATED DAILY RUNOFF

IN ALAMEDA COUNTY AREA

NOT PREVIOUSLY PUBLISHED

TABLE OF CONTENTS

RECORDED AND ESTIMATED DAILY RUNOFF IN ALAMEDA COUNTY AREA NOT PREVIOUSLY PUBLISHED 1/

1/ Gaging stations maintained by Division of Water Resources except as noted.

2/ Gaging station maintained by Alameda County Flood Control and Water Conservation District since September 1951.

3/ Gaging station maintained by San Francisco Water Department prior to September 1948, and by Alameda County Flood Control and Water Conservation District since September 1951.

RUNOFF OF ALAMEDA CREEK AT ALVARADO

Station number on Plate 2: AC-2
Drainage area:*

(Daily mean flow, in second-feet)

1950-51

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					3.0	0.1						
2			0		2.0	0.1						
3			1,250		1.5	0						
4			1,080		5.1	14						
5			448		151	564						
6			282		123	305						
7			581		70	331						
8			1,075		45	211						
9			772		29	147						
10			342		23	112						
11			176	0	19	82						
12			113	43	40	61						
13			99	62	29	51						
14			123	32	17	45						
15			294	19	11	32						
16			124	28	7.6	26						
17			96	23	5.2	21						
18		0	74	105	5.0	19						
19		1,550	53	312	3.7	13						
20		769	41	166	3.0	11						
21		523	25	103	3.0	8.1						
22		200	15	141	2.6	5.9						
23		58	9.8	112	2.1	2.7						
24		19	1.3	78	0.8	1.5						
25		8.4	0.3	58	0.3	0.7						
26		19	0.1	46	0.1	0.4						
27		0	0	29	0.1	0.2						
28				25	0	0.1						
29				17		0.1						
30				4.5		0						
31				2.9								
Runoff, in acre-feet		6,240	14,040	2,790	1,190	4,090						

1951-52

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			17	249	205	127	102	10				
2			108	145	502	119	95	9.3				
3			178	1,160	352	112	89	9.0				
4			292	72	277	112	84	8.4				
5			508	57	236	105	88	7.9				
6			196	72	211	150	94	7.6				
7			63	132	190	311	101	7.3				
8			19	172	172	203	108	5.9				
9			5.2	124	158	164	115	4.1				
10			0.8	98	143	158	122	2.1				
11			0.1	158	133	183	161	0.8				
12			0	1,770	132	188	170	0.1				
13				1,480	126	205	137	0				
14				1,320	119	190	110					
15				1,200	118	839	108					
16				1,090	117	852	51					
17				998	117	576	26					
18				920	117	498	21					
19				861	117	699	17					
20				799	163	634	15					
21				745	244	510	13					
22			0	686	200	403	11					
23			2.4	636	192	314	9.5					
24			7.3	585	190	255	8.7					
25			15	539	176	209	8.7					
26			25	494	159	179	9.0					
27			39	448	147	149	9.0					
28			89	405	139	132	9.3					
29			561	329	133	124	9.5					
30		0	852	277		115	9.5					
31			516	239		110						
Runoff, in acre-feet			6,930	36,210	10,480	17,700	3,790	140				

* Alameda Creek normally discharges into San Francisco Bay through Patterson Slough. Flow in Alameda Creek below Patterson Slough occurs only during flood conditions due to a natural barrier. Flows presented for this station are estimated from water stages in Patterson Slough.

RUNOFF OF ALAMO CREEK AT
U.S. HIGHWAY 50

Station number on Plate 2: 2-20
Drainage area: 40.4 square miles

(Daily mean flow, in second-feet)

1948-49

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1												
2						0						
3						2.2						
4						3.7						
5						0						
6												
7												
8												
9												
10						0						
11						37						
12						18						
13						6.4						
14						1.7						
15						0.8						
16						0.4						
17						0.1						
18						0						
19						2.2						
20						2.2						
21						0.4						
22						3.5						
23						6.4						
24						1.1						
25						0.6						
26						0.4						
27						0.2						
28						0.2						
29						0						
30												
31												
Runoff, in acre-feet						175						

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					0.2							
2					0							
3					0							
4					22							
5					15							
6					32							
7					7							
8					3.5							
9					2.2							
10					7.0							
11					3.5							
12					1.4							
13				0	0.8							
14				0.9	0.5							
15				0.2	0.3							
16				2.1	0.2							
17				50	0							
18				9.0								
19				2.1								
20				0.5								
21				0.2								
22				0								
23						0						
24						2.2						
25						4.0						
26						1.3						
27				0		0.6						
28				19		0.3						
29				4.4		0.2						
30				1.2		0						
31				0.5								
Runoff, in acre-feet				179	190	17						

RUNOFF OF ARROYO DE LA LAGUNA AT VERONA

Station number on Plate 2: 2-23
Drainage area: 410.0 square miles

(Daily mean flow, in second-feet)

1948-49

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					0	0	1.1	0.8	0.6	0.3	0.3	0.3
2						0.1	1.8	0.8	0.3	.3	.3	.3
3					0	8.8	1.7	2.1	0.4	.3	.3	.3
4					0.1	14	1.5	1.8	0.6	.3	.3	.3
5					3.3	4.4	0.9	1.2	0.3	.3	.3	.3
6					2.2	0.9	0.5	0.7	0.3	.3	.3	.3
7					15	0.2	0.3	0.6	0.3	.3	.3	.3
8					5.1	0.2	0.3	1.2	0.3	.3	.3	.3
9					0.8	0	0.4	1.1	0.3	.3	.3	.3
10					0	1.7	0.5	1.9	0.3	.3	.3	.3
11					0.2	115	0.3	1.1	0.3	.3	.3	.3
12					0.1	530	0.3	0.5	0.3	.3	.3	.3
13					0	284	0.5	1.0	0.7	.3	.3	.3
14						105	0.4	1.2	0.5	.3	.3	.3
15						64	0.3	0.7	0.3	.3	.3	.3
16						40	0.4	0.6	0.3	.3	.3	.3
17						27	0.3	0.9	1.1	.3	.3	.3
18						19	0.3	0.9	1.1	.3	.3	.3
19						16	0.3	1.7	0.4	.3	.3	.3
20						22	0.3	0.9	0.8	.3	.3	.3
21						25	0.3	0.6	2.1	.3	.3	.3
22						23	0.3	0.8	1.8	.3	.3	.3
23				0		33	0.3	0.8	0.3	.3	.3	.3
24				0.1		44	0.3	0.3	0.3	.3	.3	.3
25				.1		39	0.6	0.3	0.7	.3	.3	.3
26			0	.1		27	0.3	0.3	0.7	.3	.3	.3
27			7.2	.1		17	0.3	0.3	0.7	.3	.3	.3
28			0.3	.1		8.8	0.4	0.3	1.1	.3	.3	.3
29			0	.1		3.5	1.0	0.3	1.8	.3	.3	.3
30				.1		1.5	0.9	0.3	0.7	.3	.3	.3
31				.1		0.8		0.9		.3	.3	
Runoff, in acre-feet			17	5	54	2930	35	54	40	16	16	15

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.3	0.3	0.3		23	1.4	1.1	0.5	0.3	0.3	0.3	0.3
2	.3	.3	0.3		12	1.4	1.1	.5	.3	.3	.3	.3
3	.3	.3	0.3		6.0	1.4	1.1	.5	.3	.3	.3	.3
4	.3	.3	0.3		179	1.5	1.1	.5	.3	.3	.3	.3
5	.3	.3	0.3		106	1.5	1.1	.5	.3	.3	.3	.3
6	.3	.3	0.3		260	1.5	1.1	.5	.3	.3	.3	.3
7	.3	.3	0.3	0	182	1.5	2.1	.5	.3	.3	.3	.3
8	.3	.3	0.3	1.7	88	1.5	5.9	.5	.3	.3	.3	.3
9	.3	.3	0.3	2.1	56	1.5	9.4	.5	.3	.3	.3	.3
10	.3	.3	0.3	2.4	1.0	1.4	4.8	.5	.3	.3	.3	.3
11	.3	.3	1.1	12	28	1.4	2.5	.5	.3	.3	.3	.3
12	.3	.3	1.1	5.1	18	1.4	2.1	.5	.3	.3	.3	.3
13	.3	.3	1.1	3.7	14	1.4	1.8	.5	.3	.3	.3	.3
14	.3	.3	1.1	14	10	1.5	1.7	.5	.3	.3	.3	.3
15	.3	.3	0.1	11	5.4	1.5	1.7	.5	.3	.3	.3	.3
16	.3	.3	0.2	4.0	2.1	1.5	1.7	.5	.3	.3	.3	.3
17	.3	.3	0.2	159	1.2	1.5	1.7	.5	.3	.3	.3	.3
18	.3	.3	0.7	269	1.1	1.5	1.6	.5	.3	.3	.3	.3
19	.3	.3	1.8	40	1.1	1.7	1.6	.5	.3	.3	.3	.3
20	.3	.3	0.6	8.5	1.2	1.8	1.5	.5	.3	.3	.3	.3
21	.3	.3	0.1	2.2	1.2	1.2	1.5	.5	.3	.3	.3	.3
22	.3	.3	0	1.5	1.7	1.4	1.4	.5	.3	.3	.3	.3
23	.3	.3		1.4	1.7	1.5	1.3	.5	.3	.3	.3	.3
24	.3	.3		1.1	1.7	7.2	1.2	.5	.3	.3	.3	.3
25	.3	.3		0.7	1.5	12	1.1	.5	.3	.3	.3	.3
26	.3	.3		0.4	1.5	4.6	1.0	.5	.3	.3	.3	.3
27	.3	.3		2.8	1.4	2.5	0.9	.5	.3	.3	.3	.3
28	.3	.3		191	1.4	1.8	0.8	.5	.3	.3	.3	.3
29	.3	.3		295		1.8	0.7	.5	.3	.3	.3	.3
30	.3	.3		14		1.7	0.6	.5	.3	.3	.3	.3
31	.3			0.7		1.7		.5		.3	.3	
Runoff, in acre-feet	16	15	22	2050	1980	130	112	27	18	16	16	15

RUNOFF OF ARROYO DE LA LAGUNA AT
VERONA

Station number on Plate 2: 2-23
Drainage area: 410.0 square miles

(Daily mean flow, in second-feet)

1950-51

NO RECORD AVAILABLE

1951-52

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.6	0.6	8.2	347	180	44	44	17	2.9	1.7	1.9	1.8
2	.6	0.6	16	125	699	43	43	17	2.9	1.5	2.5	1.8
3	.6	0.6	26	71	278	43	41	16	3.3	2.5	4.8	1.7
4	.6	0.6	141	53	154	42	39	16	2.7	1.9	3.9	1.7
5	.6	0.6	969	46	122	42	37	15	3.3	1.9	4.3	1.6
6	.6	0.6	129	49	107	69	35	14	2.3	2.3	5.2	1.6
7	.6	0.6	44	78	96	280	42	15	2.9	1.4	3.9	1.5
8	.6	0.6	30	134	85	130	48	16	2.5	1.3	3.3	1.5
9	.6	0.6	19	72	76	84	37	15	1.8	2.5	2.7	1.4
10	.6	0.6	13	61	71	77	184	14	1.7	3.3	2.3	1.4
11	.6	0.6	8.2	180	74	77	130	13	2.5	3.3	1.9	1.2
12	.6	0.6	4.8	7,390	74	76	63	12	1.8	2.5	1.9	1.1
13	.6	0.6	2.9	3,060	69	77	48	11	1.9	1.5	1.9	0.9
14	.6	0.6	2.3	3,210	62	80	45	7.3	1.9	1.4	1.9	1.1
15	.6	0.6	2.3	2,960	53	1,660	39	8.2	1.5	2.9	1.9	1.1
16	.6	0.6	1.9	1,750	50	1,350	34	9.3	1.3	4.3	1.9	1.1
17	.6	0.6	1.9	1,040	48	1,010	31	8.2	1.3	3.3	1.9	1.1
18	.6	0.6	2.3	785	46	1,000	29	5.2	0.9	2.3	1.9	1.1
19	.6	1.1	2.3	554	45	1,320	26	4.3	1.6	3.3	1.9	1.1
20	.6	11	1.7	332	86	741	25	4.8	1.6	2.7	1.9	1.1
21	.6	1.1	1.8	287	143	392	23	5.2	1.6	2.9	1.9	1.1
22	.6	0.8	1.8	197	81	222	23	4.3	1.2	2.7	1.9	1.1
23	.6	0.8	1.6	126	72	153	21	3.7	1.3	2.9	1.9	1.1
24	.6	0.4	1.4	337	72	120	19	3.7	1.5	3.3	1.9	1.1
25	.6	0.4	1.4	2,220	60	99	19	3.7	1.9	1.4	1.9	1.1
26	.6	0.2	1.5	1,350	52	84	19	3.7	1.9	1.9	1.9	1.1
27	.6	0.4	1.5	724	48	75	19	3.9	1.7	5.2	1.9	1.1
28	.6	0.5	65	531	46	63	19	3.9	1.6	4.8	1.9	1.1
29	.6	0.4	1,040	327	44	55	18	3.7	2.3	5.6	1.9	1.1
30	.6	0.3	1,710	201		50	17	3.3	1.7	3.3	1.9	1.1
31	.6		962	133		46				1.9	1.9	1.1
Runoff, in acre-feet	37	56	12,290	57,000	6,130	19,050	2,410	550	118	166	148	75

RUNOFF OF ARROYO MOCHO 6.5 MILES SOUTHEAST OF LIVERMORE

Station number on Plate 2: 2-25
Drainage area: 38.3 square miles

(Daily mean flow, in second-feet)

1948-49

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				0.9	0.9	8.0	1.7	0.1				
2				0.4	1.7	10	0.9	.1				
3				0.4	2.8	40	0.5	.1				
4				0.5	2.8	40	0.4	.1				
5				0.5	1.7	10	0.4	.1				
6				0.9	1.7	4.8	0.4	.1				
7				0.9	2.8	2.0	0.9	.1				
8				0.9	10	2.8	0.9	.1				
9				0.4	7.0	2.8	0.7	0				
10				0.4	4.8	7.5	0.5					
11				0.4	4.8	65	0.5					
12				0.9	4.8	40	0.5					
13				1.3	2.8	20	0.9					
14				1.7	1.7	8.4	1.7					
15				0.9	1.7	8.6	1.7					
16				0.4	4.8	8.4	1.7					
17				0.4	4.8	7.5	0.9					
18				0.9	3.5	4.8	0.4					
19				1.3	2.5	4.8	0.3					
20				2.0	1.7	7.7	0.3					
21			0	4.8	1.7	2.8	0.3					
22			0.1	3.0	4.8	6.5	0.3					
23			0.1	2.8	4.8	9.3	0.3					
24			0.1	2.8	7.0	10	0.3					
25			0.1	3.5	7.0	8.6	0.1					
26			0.2	3.5	7.0	6.5	0.1					
27			0.4	3.0	5.5	5.5	0.1					
28			0.5	2.8	4.8	2.0	0.1					
29			0.9	2.4		1.6	0.1					
30			1.7	1.7		1.7	0.1					
31			1.7	0.5		1.7						
Runoff, in acre-feet			11	94	218	714	35	1				

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					1.9	0.7	0.7	0.2				
2					1.9	.7	0.7	.2				
3					1.7	.7	0.7	.2				
4					2.1	.7	0.7	.2				
5					11	.7	0.7	.2				
6					12	.7	0.7	.2				
7					6.6	.6	0.7	.2				
8					4.6	.5	0.7	.1				
9					3.8	.5	1.2	.1				
10				0	3.2	.5	4.5	.1				
11				0.5	2.3	.5	3.5	.1				
12				0.6	1.7	.5	2.1	.1				
13				2.1	1.5	.5	1.6	.1				
14				0.6	1.6	.5	0.7	0				
15				0.6	1.2	.5	0.7					
16				0.6	1.7	.5	0.7					
17				25	1.2	.5	0.7					
18				40	1.7	.5	0.6					
19				25	1.3	.5	0.6					
20				18	1.7	.5	0.5					
21				18	1.2	.6	0.5					
22				15	1.6	.6	0.5					
23				14	2.1	.7	0.4					
24				3.2	1.6	.7	0.4					
25				1.5	1.3	.7	0.3					
26				1.6	1.1	.7	0.3					
27				1.6	0.8	.7	0.3					
28				9.5	0.8	.7	0.2					
29				18		.7	0.2					
30				9.0		.7	0.2					
31				2.1		.7						
Runoff, in acre-feet				410	149	35	51	4				

RUNOFF OF ARROYO LAS POSITAS AT
U.S. HIGHWAY 50

Station number on Plate 2: 2-22
Drainage area: 69.5 square miles

(Daily mean flow, in second-feet)

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1												
2												
3					0							
4					0.7							
5					1.4							
6					2.0							
7					0.3							
8					0							
9					0							
10					0.2							
11					0.2							
12					0							
13												
14												
15												
16				0								
17				8.0								
18				0.9								
19				0								
20												
21												
22												
23												
24												
25												
26												
27				0								
28				2.5								
29				1.1								
30				0								
31												
Runoff, in acre-feet				25	10							

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1941-42

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				101	93	10	58	15	11	1.7		
2				69	87	4.7	84	18	7.5	1.6		
3				48	73	9.7	112	19	6.4	1.4		
4				34	70	8.0	146	19	7.7	1.3		
5				27	108	8.0	182	22	5.9	1.4		
6				24	413	6.7	167	24	6.1	1.0		
7				20	461	6.9	127	26	6.1	1.0		
8				18	272	7.5	82	26	6.7	0.7		
9				16	156	8.0	56	26	6.7	0.3		
10				14	99	10	42	23	5.3	0.7		
11				11	68	13	34	26	4.1	0.2		
12				9.7	57	22	32	26	3.4	0.2		
13				9.7	49	29	32	21	3.6	0.4		
14				9.4	43	40	127	16	4.9	0.4		
15				10	42	80	56	15	5.6	0.4		
16				9.4	41	112	51	15	5.1	0.3		
17				9.7	34	200	47	16	4.3	0.3		
18				11	29	173	42	16	3.2	0.2		
19				11	25	136	34	16	2.9	0.2		
20				8.0	22	107	30	13	2.8	0.2		
21				2.8	21	95	26	11	3.2	0.1		
22				1.7	21	87	21	11	3.4	0		
23				3.1	21	79	17	11	2.9			
24				167	20	64	15	12	2.3			
25				789	15	50	14	15	1.9			
26				293	11	46	13	14	1.9			
27				293	11	40	11	8.4	1.9			
28				338	10	34	13	10	1.9			
29			0	210		33	14	9.4	1.9			
30			264	127		34	14	9.4	1.9	0		
31			154	335		40		11		0.1		
Runoff, in acre-feet			831	6,015	4,710	3,175	3,375	1,030	262	20		

1942-43

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			4.9	6.7								
2			4.3	5.9								
3			3.4	5.3								
4			2.9	5.3								
5			2.6	0								
6			3.1									
7			6.7									
8			7.5									
9			6.4									
10			5.3									
11			4.3									
12			4.7									
13			4.9									
14			5.1									
15			5.9									
16			5.1									
17		0	4.7									
18		14	4.1									
19		24	3.8									
20		11	4.3									
21		7.2	5.1									
22		4.9	5.3									
23		4.7	6.1									
24		4.7	20									
25		4.5	49									
26		4.1	32									
27		4.3	18									
28		4.7	15									
29		5.1	15									
30		5.1	11									
31			8.4									
Runoff, in acre-feet		197	550	46								

Note - Slight discrepancies between monthly flow and summation of daily flows is due to rounding of daily flow values.

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1943-44

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					18	387	7.5	2.6	0.9	0.3		
2				0	14	189	7.7	2.8	.9	.3		
3				0.7	67	120	8.0	2.8	.9	.3		
4				0.7	146	651	8.4	2.6	.8	.3		
5				0.4	66	536	8.1	2.3	.6	.2		
6				0.3	41	210	8.0	2.2	.6	.1		
7				0	6.4	167	8.0	2.0	.6	.1		
8				0.2	39	115	8.0	2.0	.6	.2		
9				1.9	122	71	8.0	2.0	.7	.3		
10				2.6	70	51	6.4	1.9	.8	.1		
11				2.6	48	45	4.3	1.8	.8	.1		
12				3.4	32	40	3.8	1.3	.7	.1		
13				2.9	25	31	3.2	1.0	.6	.1		
14				2.6	15	27	3.1	12	.5	.1		
15				3.1	16	22	3.1	2.3	.4	.1		
16				2.5	16	22	3.1	3.1	.4	.1		
17				2.2	16	21	3.1	3.4	.4	.2		
18				1.9	15	20	3.2	3.2	.4	.2		
19				2.0	14	17	3.2	2.2	.4	.1		
20				1.9	19	14	3.6	1.9	.4	.1		
21				1.9	31	13	3.6	1.4	.4	.1		
22				1.9	281	13	2.9	1.6	.4	.1		
23				9.7	359	12	2.5	1.8	.4	.2		
24				16	125	12	2.3	1.4	.3	.2		
25				17	60	12	2.3	1.0	.3	.2		
26				12	57	12	2.3	0.9	.3	.1		
27				8.7	54	12	2.9	0.9	.4	.1		
28				6.7	82	11	3.6	0.9	.3	.1		
29				5.3	918	10	3.4	0.9	.3	.1		
30				5.1		9.7	3.1	0.9	.3	.1		
31				17		8.4		0.8		0		
Runoff, in acre-feet				366	5,500	5,725	274	113	26	10		

1944-45

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				7.7	140	20	75	18	11	4.9	0.8	
2				5.3	4,580	20	59	18	11	5.3	.4	
3				4.3	1,580	21	51	18	11	6.4	.2	
4				3.9	1,840	27	49	17	11	6.4	.1	
5				3.6	449	27	45	16	11	7.2	0	
6				3.4	189	27	43	16	11	7.5		
7				3.6	146	27	42	15	11	5.9		
8				3.8	104	27	40	15	11	4.9		
9				3.6	83	26	38	15	11	3.4		
10				3.6	70	24	38	15	11	3.4		
11				3.6	61	21	35	15	11	3.4		
12				3.6	51	21	34	16	10	3.4		
13			0	3.8	44	21	34	16	9.7	3.4		
14			0.4	3.8	42	21	33	15	9.0	3.4		
15			1.0	2.5	40	101	30	16	8.4	3.1		
16			1.1	2.6	37	89	22	16	8.0	2.2		
17			1.1	3.1	34	110	24	16	8.0	2.2		
18			1.1	3.2	33	83	27	16	7.7	2.9		
19			1.0	3.2	31	60	26	16	7.5	4.5		
20			0.8	3.2	29	52	27	14	7.2	4.7		
21			0.8	2.9	27	48	26	11	6.9	4.1		
22			1.1	2.8	25	59	22	12	7.2	3.2		
23			1.6	3.1	23	200	18	12	7.5	2.8		
24			1.8	3.2	21	123	20	13	7.7	2.2		
25			1.8	3.4	20	115	21	13	5.9	2.0		
26			1.7	3.2	18	352	21	14	5.9	2.0		
27			1.7	3.1	19	293	21	14	6.1	1.9		
28			3.1	2.2	20	177	20	11	5.9	1.7		
29			20	2.5		136	20	11	5.6	1.3		
30			26	2.2		108	17	11	5.1	1.0		
31			17	2.3		87		11		0.9		
Runoff, in acre-feet			167	210	19,380	5,010	1,950	897	516	214	3	

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1945-46

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				150*	15	19	57	11	11	5.3*		
2				100*	16	19	54	12	11	5.0*		
3				75*	21	18	49	12	11	4.8*		
4				50*	22	17	41	11	11	4.7*		
5				30*	22	16	37	11	11	4.2*		
6				120*	21	16	32	9.7	11	4.2*		
7				380	21	16	28	11	11	3.9*		
8				297	24	16	26	11	11	3.3*		
9				225	22	15	24	11	11	3.3*		
10				173	19	14	22	11	7.2	3.1*		
11				129	19	14	21	11	6.1	3.0*		
12				87	19	14	20	10	5.9	2.8*		
13				48	18	16	20	9.7	5.9	2.0*		
14				27	18	17	18	9.7	6.1	1.1*		
15				22	19	17	17	9.7	5.9	0.9*		
16				21	24	16	17	9.7	6.1	0.7*		
17				20	29	15	17	9.7	6.4	0.4*		
18				19	27	14	16	9.7	5.9	0.3*		
19				16	27	15	16	9.7	5.6	0.3*		
20				14	27	16	16	9.7	5.7	0.3*		
21				11	26	16	15	10	5.3	0.2*		
22				12	26	16	13	11	5.3	0.2*		
23				14	25	16	13	11	5.6	0.1*		
24				17	23	16	14	11	5.6	0.1*		
25				17	21	18	14	11	5.6	0.1*		
26			0	16	19	14	14	11	5.3	0.1*		
27			120*	16	19	14	13	11	5.3	0.1*		
28			417	16	19	15	12	11	5.3	0 *		
29			300*	16		26	11	11	5.3			
30			250*	15		54	11	11	5.3			
31			200*	15		61		11				
Runoff, in acre-feet			828	3,260	1,210	1,160	1,350	677	434	108		

1946-47

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				12	11	11	15	5.6	4.3	1.4		
2				5.3	11	13	15	5.6	4.1	1.3		
3				11	11	16	15	5.1	2.9	1.3		
4				11	10	26	15	5.9	3.0	1.0		
5				11	9.7	29	16	5.9	3.2	1.1		
6				9.7	9.4	22	16	5.3	3.4	1.4		
7				8.0	9.0	20	15	5.3	3.4	1.4		
8				7.5	9.7	19	12	5.3	3.4	1.1		
9				6.9	11	19	12	5.3	3.8	1.0		
10				6.9	12	24	12	5.3	3.9	1.1		
11				7.7	15	51	13	5.3	3.8	1.0		
12				8.0	18	40	14	5.6	3.6	1.1		
13				8.0	71	30	13	5.1	3.6	1.2		
14				7.7	59	24	11	5.1	3.6	1.3		
15			0	6.9	43	21	13	5.1	3.6	0.9		
16			9.7	7.5	36	20	8.0	4.9	3.4	0.7		
17			8.4	7.5	30	19	8.0	4.9	3.6	0.3		
18			9.0	8.0	26	16	8.4	4.9	3.4	0.1		
19			8.7	8.0	21	15	8.0	4.9	3.1	0		
20			8.4	8.0	20	14	7.7	4.3	2.8			
21			8.0	8.4	17	13	8.0	4.1	2.6			
22			7.2	7.7	16	12	8.0	4.3	2.3			
23			6.9	7.7	16	12	7.7	4.3	2.2			
24			7.5	8.0	15	11	7.5	4.5	1.9			
25			9.4	8.0	13	11	7.5	4.5	1.8			
26			15	8.0	11	11	7.2	4.5	1.6			
27			23	7.7	11	11	6.9	4.3	1.6			
28			38	9.4	11	13	6.9	4.1	1.9			
29			25	11		15	6.7	3.9	1.9			
30			17	11		16	6.4	3.8	1.8			
31			14	11		16		3.9				
Runoff, in acre-feet			423	522	1,100	1,100	632	262	181	38		

* Estimated.

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1947-48

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1							8.4	34	5.9	1.6	0.3	
2							8.1	23	5.9	1.4	.6	
3							8.4	20	5.9	1.7	.3	
4							14	17	5.6	2.2	.2	
5							34	12	4.9	2.3	.1	
6							45	8.7	5.1	1.9	.1	
7							30	7.7	4.5	1.8	.2	
8							24	7.7	3.8	1.1	.3	
9							21	7.5	3.6	0.8	.3	
10							28	7.7	3.4	0.9	.2	
11							42	8.0	3.4	1.0	.1	
12							40	7.7	3.6	0.9	0	
13							30	7.5	4.5	1.7		
14							24	6.7	5.9	1.4		
15							18	5.9	8.7	1.2		
16							14	5.9	9.4	1.0		
17							13	6.4	10	1.4		
18							13	6.9	13	1.9		
19							11	5.3	14	1.8		
20							11	5.3	18	1.1		
21							9.7	4.3	9.7	0.5		
22							9.7	4.3	3.4	0.5		
23						0	8.0	4.9	3.8	0.8		
24						1.4	8.0	4.9	3.6	0.5		
25						56	8.7	5.3	4.1	0.5		
26						30	8.0	4.5	4.3	0.8		
27						25	8.0	5.3	4.9	0.9		
28						20	8.4	4.3	3.8	0.9		
29						15	9.0	4.5	2.2	0.8		
30						12	38	6.1	1.9	0.7		
31						9.7		5.6		0.4		
Runoff, in acre-feet						348	1,110	526	363	714	2	

1948-49

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					0.1	6.9	14	3.7	3.3	0.4		
2					0.1	6.7	11	4.3	3.3	.4		
3					0.4	252	12	4.3	3.3	.4		
4					0.7	156	11	4.3	3.3	.4		
5					0.9	95	11	4.3	3.3	.4		
6					0.9	50	11	4.3	3.3	.4		
7					3.4	38	12	4.3	3.3	.2		
8					27	31	12	4.3	3.3	.2		
9					19	31	13	4.3	3.3	.2		
10					16	49	11	4.3	3.3	.2		
11					16	555	7.5	4.3	3.3	.2		
12					21	760	7.2	4.3	3.3	.1		
13					14	312	6.9	4.3	3.3	.1		
14					10	136	6.7	4.3	3.3			
15					8.7	87	6.1	4.3	3.3			
16					8.7	68	5.3	4.3	3.3			
17					9.7	62	5.3	3.9	3.3			
18					10	58	5.3	3.3	3.3			
19					10	45	4.3	3.3	3.3			
20					9.4	64	3.3	3.0	2.6			
21					7.7	47	4.3	2.6	1.9			
22					10	42	4.3	3.3	1.9			
23				0	16	77	4.3	3.3	1.9			
24				.2	14	87	4.3	3.3	1.9			
25				.1	14	60	4.3	3.3	1.9			
26			0	.1	9.7	42	3.7	3.3	1.9			
27			.1		9.4	34	3.3	3.3	1.9			
28			0		6.9	27	3.3	3.3	1.9			
29						23	3.7	3.3	1.9			
30						20	3.7	3.3	1.9			
31						18		3.3				
Runoff, in acre-feet				1	541	6620	431	236	169	7		

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					14	7.7	12	6.1	3.7			
2					14	7.2	9.4	5.6	3.7			
3					11	5.3	6.4	6.7	3.5			
4					18	5.6	5.1	7.2	3.3			
5					152	6.4	5.9	7.2	3.3			
6					215	6.1	6.7	7.2	3.2			
7					136	5.4	9.4	6.7	3.2			
8					77	5.1	12	6.1	3.2			
9					51	5.1	36	5.1	3.1			
10					50	5.1	37	5.3	2.8			
11				0	57	4.9	26	5.1	2.5			
12				0.3	51	5.6	22	5.1	2.2			
13				0.6	32	5.3	19	5.1	1.9			
14				8.1	30	5.1	18	4.9	1.7			
15				37	26	5.6	17	4.9	1.5			
16				14	24	5.9	16	4.7	1.3			
17				573	20	6.1	14	4.7	1.1			
18				110	15	6.1	13	4.5	0.9			
19				38	14	6.4	11	4.5	0.8			
20				21	14	6.4	9.7	4.5	0.7			
21				9.7	13	7.7	8.7	4.3	0.6			
22				8.0	10	8.0	8.0	4.3	0.5			
23				6.7	10	6.3	8.0	4.1	0.4			
24				6.7	10	23	8.0	4.1	0.3			
25				4.5	9.7	86	8.0	3.9	0.3			
26				3.2	9.4	76	7.2	3.9	0.2			
27				2.8	9.4	50	6.7	3.7	0.1			
28				374	9.0	35	6.1	3.7	0.1			
29				152		26	7.2	3.7	0.1			
30				60		20	6.7	3.7	0			
31				31		15		3.7				
Runoff, in acre-feet				2,900	2,180	938	753	307	99			

1950-51

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			89	26	34	40	32	23	4.7	1.5	0.1	
2			86	23	30	47	33	17	3.2	1.5	.2	
3			429	23	30	51	31	17	2.9	1.5	.1	
4			1,880	24	30	58	30	22	3.9	1.4	.1	
5			1,410	21	74	435	27	22	3.9	1.2	.2	
6			233	19	81	247	24	22	3.9	1.2	.1	
7			406	17	60	239	25	21	3.9	1.2	.1	
8			892	14	48	193	27	18	3.9	1.2		
9			505	15	45	138	26	16	3.4	1.1	.1	
10			244	21	44	116	25	14	3.1	1.2	.1	
11			122	51	42	98	23	14	2.9	1.1	.1	
12			99	73	50	82	23	14	2.8	0.9	.2	
13			81	59	42	71	20	14	2.0	0.8	.2	
14			92	42	42	59	23	12	3.3	0.7	.1	
15			93	42	36	54	24	9.0	2.0	0.9	0	
16			75	42	34	56	24	9.0	1.9	0.7		
17		0	66	34	34	55	24	9.0	1.8	0.8		
18		1,770	50	90	30	51	19	9.4	1.5	0.5		
19		3,240	48	236	27	50	20	9.4	1.5	0.5		
20		1,020	40	138	27	48	18	8.7	1.7	0.4		
21		602	35	104	28	40	18	7.5	2.0	0.4		
22		303	32	89	28	40	19	6.7	2.3	0.5		
23		171	32	74	30	36	21	6.4	2.2	0.5		
24		132	32	68	34	35	20	6.9	1.5	0.5		
25		107	30	62	28	35	18	7.7	1.5	0.4		
26		92	28	51	28	39	18	5.9	1.5	0.3		
27		108	27	42	32	35	18	5.3	1.5	0.3		
28		110	27	37	34	28	21	4.3	1.5	0.3		
29		98	22	35		27	26	3.8	1.5	0.4		
30		89	22	42		28	25	4.1	1.5	0.4		
31			26	40		31		4.3		0.4		
Runoff, in acre-feet		15,560	12,390	3,280	2,150	5,080	1,390	717	149	49	3	

RUNOFF OF ARROYO DEL VALLE AT
UNITED STATES VETERANS ADMINISTRATION HOSPITAL

Station number on Plate 2: 2-26
Drainage area: 149.0 square miles

(Daily mean flow, in second-feet)

1951-52

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			69	160	138	57	76	32	13	6.4	2.1	0.8
2			75	96	310	55	68	31	13	6.0	2.1	.8
3			31	59	210	50	60	31	13	5.4	2.1	.8
4			85	28	160	51	58	31	11	5.0	2.0	.8
5			700	38	140	50	55	30	10	4.6	2.0	.8
6			430	37	120	59	42	30	10	4.5	2.0	.8
7			66	59	106	129	55	30	10	4.2	1.9	.8
8			31	63	104	140	69	30	10	4.1	1.9	.8
9			26	61	100	112	56	30	10	4.0	2.0	.8
10			21	58	84	127	41	29	10	3.5	2.0	.8
11			17	138	80	125	170	26	11	3.2	2.0	.8
12			16	3,400	80	122	100	24	10	3.2	2.0	.8
13			13	790	74	139	78	22	10	3.2	2.0	.8
14			12	830	59	170	74	20	10	3.1	1.9	.8
15			12	1,750	55	1,100	59	19	9.5	3.0	1.9	.8
16			12	785	52	740	54	19	9.5	3.0	1.9	.8
17			12	560	58	500	50	18	8.8	3.0	1.7	.8
18			12	435	58	440	48	18	8.0	3.0	1.6	.8
19			11	310	58	520	45	16	7.0	2.8	1.5	.8
20			11	280	95	420	41	17	6.9	2.8	1.4	.8
21			11	212	160	330	38	16	6.9	2.8	1.2	.8
22		0	10	180	110	250	37	16	6.4	2.5	1.2	.8
23		0.6	10	138	130	200	36	15	6.4	2.5	1.1	.8
24		.6	9	300	113	170	35	15	6.4	2.5	1.2	.8
25		.5	9	1,080	96	158	34	14	6.6	2.4	1.1	.8
26		.5	10	690	79	140	34	14	6.6	2.4	1.0	.8
27		.6	11	410	84	120	34	14	6.6	2.4	1.0	.8
28		.6	35	285	68	109	34	13	6.6	2.4	0.9	.8
29		.7	85	232	60	100	33	13	6.6	2.2	0.8	.8
30		.7	620	156		86	32	13	6.6	2.2	0.8	.8
31			340	135		80		13		2.2	0.8	
Runoff, in acre-feet		2	5,560	27,300	6,040	13580	3,260	1,310	530	206	97	48

RUNOFF OF DRY CREEK AT STATE ROUTE 9

Station number on Plate 2: 2-32
Drainage area: 9.4 square miles

(Daily mean flow, in second-feet)

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					4.3	1.3	1.5	0				
2					3.5	1.3	1.4					
3					3.2	1.3	1.4					
4					15	1.2	1.4					
5					11	1.2	1.4					
6					42	1.1	1.4					
7					11	1.1	2.7					
8					8.0	1.1	2.6					
9					6.2	1.1	2.1					
10					7.7	1.0	1.7					
11					5.5	0.9	1.6					
12					4.7	0.8	1.5					
13					3.8	0.7	1.5					
14					3.5	0.7	1.4					
15					2.7	0.7	1.4					
16				0	2.4	0.7	1.3					
17				60	2.2	0.6	1.1					
18				23	2.1	0.6	1.0					
19				7.1	1.9	0.6	0.9					
20				3.5	1.7	0.6	0.8					
21				3.0	1.6	0.6	0.7					
22				4.1	1.5	0.8	0.7					
23				3.9	1.5	1.0	0.6					
24				2.4	1.4	27	0.5					
25				1.7	1.4	9.2	0.5					
26				1.3	1.4	5.7	0.5					
27				2.1	1.4	3.9	0.5					
28				131	1.3	2.9	0.5					
29				15		2.4	0.5					
30				8.0		1.9	0.5					
31				5.7		1.6	0.5					
Runoff, in acre-feet				539	306	150	72					

1950-51

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			5.1	2.8	5.8	5.0	3.1	1.6	2.5			
2			5.1	2.8	5.1	4.5	3.0	1.6	2.5			
3			81	3.5	4.5	16	2.9	1.6	2.5			
4			37	3.3	14	37	2.8	1.6	2.6			
5			40	2.8	45	72	2.7	1.6	2.6			
6			60	2.5	17	52	2.6	1.7	2.6			
7			92	2.4	12	36	2.6	1.7	2.6			
8			67	2.4	10	20	2.5	1.7	2.6			
9			28	2.4	10	20	2.4	1.7	2.1			
10			16	4.4	9.5	12	2.3	1.7	1.7			
11			11	6.9	11	9.7	2.2	1.7	1.5			
12			8.5	7.9	11	8.3	2.1	1.7	1.2			
13			9.0	6.3	8.5	7.7	2.1	1.7	1.0			
14			22	5.5	7.7	7.1	2.1	1.7	0.8			
15			15	6.2	7.1	6.3	2.1	1.8	0.8			
16			11	6.2	6.5	5.8	2.0	1.8	0.8			
17		0	8.3	5.5	6.5	5.5	2.0	1.8	0.8			
18		12	6.9	1.6	6.4	4.8	2.0	1.8	0.8			
19		18	6.0	21	5.8	4.7	2.0	1.8	0.7			
20		46	5.5	13	5.7	4.7	1.8	1.8	0.7			
21		26	4.8	9.7	5.8	4.5	1.8	1.8	0.7			
22		18	4.4	56	5.7	4.4	1.8	1.9	0.7			
23		13	3.9	28	4.8	4.1	1.8	1.9	0.6			
24		9.5	3.8	19	4.4	3.9	1.7	1.9	0.5			
25		7.5	3.4	14	4.2	3.8	1.7	2.0	0.4			
26		6.5	3.3	12	4.7	3.6	1.6	2.1	0.3			
27		5.1	3.1	9.9	4.1	3.5	1.6	2.2	0.2			
28		5.1	2.9	8.5	4.2	3.4	1.6	2.3	0.1			
29		5.1	2.7	8.3		3.3	1.6	2.3	0			
30		5.1	2.7	7.3		3.2	1.6	2.4				
31			2.7	6.2		3.1		2.5				
Runoff, in acre-feet		351	1,140	572	493	753	127	114	73			

RUNOFF OF DRY CREEK AT STATE ROUTE 9

Station number on Plate 2: 2-32
Drainage area: 9.4 square miles

(Daily mean flow, in second-feet)

1951-52

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1				44	41	12	12	7.7	6.0	5.7	5.1	
2				28	41	11	11	7.7	6.0	5.3	5.1	
3				19	28	14	10	7.7	6.0	5.3	5.0	
4				14	22	13	9.5	7.5	6.0	5.3	5.0	
5				13	20	11	9.2	7.5	6.0	5.3	4.7	
6			0	36	17	23	9.0	7.5	6.0	5.3	4.5	
7			11	74	16	27	19	7.5	6.0	5.3	4.5	
8			10	58	16	19	9.5	7.5	6.0	5.3	4.2	
9			8.8	32	15	12	10	7.3	6.0	5.3	4.2	
10			7.9	24	14	14	22	7.3	6.0	5.3	4.2	
11			7.7	22	14	13	11	7.3	6.0	5.3	4.1	
12			7.3		14	15	9.5	7.1	6.0	5.3	4.1	
13			6.9		13	13	9.5	7.1	6.0	5.3	4.1	
14			6.3		13	13	9.5	6.9	6.0	5.3	4.1	
15			6.2		12	185	9.0	6.9	6.0	5.3	0	
16			6.0		12	50	8.3	6.9	6.0	5.3		
17			6.0		13	34	8.3	6.9	6.0	5.3		
18			6.5		12	45	8.3	6.9	6.0	5.3		
19			7.5		13	42	8.3	6.9	6.0	5.3		
20			6.9		25	31	8.1	6.9	6.0	5.3		
21			6.3		16	28	8.1	6.9	6.0	5.3		
22			6.0		15	24	8.1	6.9	6.0	5.3		
23			6.2		15	21	8.1	6.9	6.0	5.3		
24			6.2		15	19	8.1	6.7	6.0	5.3		
25			6.3		14	16	7.9	6.7	6.0	5.3		
26			6.3		13	15	7.9	6.5	6.0	5.3		
27			6.3		12	15	7.9	6.5	5.8	5.3		
28			175		12	14	7.7	6.3	5.7	5.3		
29			468		12	13	7.7	6.2	5.7	5.3		
30			126			12	7.7	6.0	5.5	5.3		
31			69			12		6.0		5.1		
Runoff, in acre-feet			1,960	4,200*	990	1,560	580	430	350	330	120	

* Record missing between January 12th and 31st inclusive, monthly runoff estimated.

RUNOFF OF PATTERSON SLOUGH AT STATE ROUTE 17

Station number on Plate 2: AC-1
Drainage area:*

(Daily mean flow, in second-feet)

1950-51

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					0.4							
2			0		0.1							
3			4,450		0.1	0						
4			3,650		2.5	14						
5			1,080		250	1,160						
6			563		174	634						
7			1,540		77	707						
8			3,610		39	374						
9			2,290		20	226						
10			738		14	152						
11			290	0	11	97						
12			154	53	34	63						
13			127	64	20	48						
14			174	23	8.5	39						
15			597	10	4.6	23						
16			177	19	2.2	17						
17			122	14	1.1	12						
18		0	83	187	1.1	10						
19		5,930	51	649	0.6	5.9						
20		2,280	35	266	0.4	4.1						
21		1,330	16	135	0.4	2.6						
22		347	7.0	213	0.3	1.5						
23		59	3.6	152	0.2	0.3						
24		97	0.1	90	0	0.1						
25		2.7	0.3	59		0						
26		10	0	41								
27		0		20								
28				16								
29				9.1								
30				0.9								
31				0.4								
Runoff, in acre-feet		19,950	39,150	4,010	1,310	7,120						

1951-52

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			30	473	361	181	133	3.7				
2			153	221	1,275	165	120	3.2				
3			378	4,000	771	152	109	3.1				
4			657	81	549	152	101	2.7				
5			1,300	57	437	138	107	2.4				
6			337	86	374	239	119	2.2				
7			66	193	323	659	131	2.1				
8			11	284	281	354	144	1.5				
9			1.1	177	215	263	157	0.7				
10			0	125	216	250	172	0.2				
11			0.1	321	195	305	255	0.1				
12			0	7,140	192	317	275	0				
13				5,520	181	361	204					
14				4,780	165	344	148					
15				4,197	163	2,626	144					
16				3,679	161	2,624	48					
17				3,255	161	1,524	17					
18				2,912	161	1,256	12					
19				2,657	161	1,996	4.1					
20				2,398	260	1,738	7.3					
21				2,178	460	1,286	5.7					
22			0	1,941	347	931	4.6					
23			0.2	1,747	327	654	3.4					
24			2.1	1,558	223	485	2.9					
25			7.0	1,389	290	371	2.9					
26			16	1,253	252	296	3.1					
27			32	1,075	226	229	3.1					
28			109	937	208	192	3.2					
29			1,500	701	195	177	3.4					
30		0	2,620	549		157	3.4					
31			1,310	445		148						
Runoff, in acre-feet			16,900	105,800	18,100	40,790	4,850	40				

* Alameda Creek normally discharges into San Francisco Bay through Patterson Slough. Flow in Alameda Creek below Patterson Slough occurs only during flood conditions due to a natural barrier. Flows presented for this station are estimated from water stages in Patterson Slough.

RUNOFF OF SAN ANTONIO CREEK 1 MILE EAST OF CALAVERAS ROAD

Station number on Plate 2: 2-24
Drainage area: 38.7 square miles

(Daily mean flow, in second-feet)

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
1					17	3.3	11	0.5			
2					13	2.3	11	.5			
3					11	1.6	11	.5			
4					39	1.9	11	.5			
5					45	1.9	11	.5			
6					46	1.9	11	.5			
7					26	2.3	11	.5			
8					12	2.3	17	.5			
9					8.5	2.3	18	.5			
10				0	16	2.3	19	.5			
11				38	25	2.6	18	.5			
12				21	23	2.6	16	.5			
13				22	9.2	2.6	11	.5			
14				156	10	2.6	7.8	.5			
15				56	10	2.6	8.5	.5			
16				64	10	2.6	9.8	.4			
17				298	11	2.6	11	.4			
18				169	10	2.6	10	.4			
19				80	11	2.6	8.5	.4			
20				59	10	3.6	5.7	.4			
21				54	6.4	7.8	4.4	.4			
22				47	4.4	20	4.0	.4			
23				22	4.4	37	3.6	.4			
24				11	4.4	56	3.3	.4			
25				11	4.4	69	3.3	.4			
26				9.8	4.4	62	3.3	.4			
27				13	4.4	37	3.0	0			
28				184	4.4	31	2.6				
29				82		22	2.6				
30				16		14	2.6				
31				18		11					
Runoff, in acre-feet				2,722	761	792	51	23			

1950-51

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1			11	9.2	5.7	23	7.1	4.4	3.3	0.6		
2			12	8.5	4.4	25	7.1	4.4	3.3	.6		
3			709	7.8	4.4	25	7.1	4.4	3.0	.5		
4			335	7.1	4.4	59	6.4	4.4	3.0	.5		
5			114	7.1	56	299	6.4	4.4	2.6	.4		
6			197	7.1	34	208	6.4	4.4	2.3	.4		
7			250	6.4	29	165	6.4	4.4	2.3	.4		
8			728	5.7	25	128	5.7	4.4	1.9	.3		
9			169	4.4	22	96	5.7	4.4	1.9	.2		
10			82	4.4	22	82	5.7	4.4	1.9	.1		
11			62	47	22	595	5.0	4.4	1.9	.1		
12			52	41	41	553	5.0	4.4	1.6	0		
13			37	37	41	514	5.0	4.4	1.6			
14			82	37	34	475	5.0	4.4	1.6			
15			56	34	25	440	5.0	4.4	1.6			
16			47	26	20	26	5.0	4.4	1.6			
17		0	39	22	19	25	5.0	4.4	1.6			
18		3,920	29	110	20	23	5.0	4.4	1.2			
19		587	25	128	20	21	5.0	4.4	1.2			
20		252	22	88	21	19	5.0	4.4	1.2			
21		82	17	77	21	17	5.0	4.4	0.9			
22		28	17	77	21	16	5.0	4.4	0.9			
23		18	14	56	21	14	5.0	4.4	0.9			
24		12	14	52	20	13	4.4	4.4	0.9			
25		9.8	14	41	21	12	4.4	4.4	0.9			
26		4.4	13	25	22	11	4.4	4.0	0.9			
27		7.8	13	20	22	9.8	4.4	3.6	0.9			
28		9.8	12	13	22	9.2	4.4	3.3	0.8			
29		9.8	11	9.8		8.5	4.4	3.0	0.8			
30		8.5	10	8.5		7.8	4.4	3.0	0.7			
31			9.8	7.1		7.8		3.3	0.7			
Runoff, in acre-feet		9,600	6,210	1,830	1,280	7,660	310	252	97	8		

RUNOFF OF TASSAJARA CREEK AT
U.S. HIGHWAY 50

Station number on Plate 2: 2-21
Drainage area: 27.9 square miles

(Daily mean flow, in second-feet)

1948-49

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1												
2						0						
3						0.2						
4						0.1						
5						0						
6												
7												
8												
9												
10						0						
11						0.2						
12						28						
13						2.0						
14						0.4						
15						0.1						
16						0						
17												
18						0						
19						0.2						
20						0.7						
21						0.1						
22						0						
23						0.7						
24						0.2						
25						0						
26												
27												
28												
29												
30												
31												
Runoff, in acre-feet						65						

1949-50

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1												
2												
3					0							
4					0.7							
5					1.6							
6					3.7							
7					1.0							
8					0.6							
9					0.4							
10					0.7							
11					0.7							
12					0.4							
13				0	0.2							
14				0.2	0.2							
15				0	0.1							
16				0	0							
17				4.4								
18				1.9								
19				0.4								
20				0								
21												
22												
23												
24						0						
25						1.0						
26						0						
27				0								
28				1.0								
29				0.7								
30				0.2								
31				0								
Runoff, in acre-feet				17	20	2						

APPENDIX C

GROUND WATER GEOLOGY OF ALAMEDA COUNTY AREA

TABLE OF CONTENTS

GROUND WATER GEOLOGY
OF ALAMEDA COUNTY AREA

TABLES

FIGURES

GROUND WATER GEOLOGY
OF ALAMEDA COUNTY AREA

This report is concerned with the geology of the Alameda County Area as defined in the main body of this bulletin. In brief, this area includes the southern part of Alameda County from San Francisco Bay eastward to and including Livermore Valley and a portion of its surrounding uplands.

The geology of the upland parts of the Alameda County Area has been reported in published literature[1/] by A. C. Lawson (36), C. W. Clark (34), C. A. Hall, Jr. (20), and M. D. Crittenden (7); and as unpublished theses or reports by J. M. Harding (22), M. R. Erickson (17), and R. G. Thomas (13). Various studies concerning the valley areas and ground water problems have been made by a number of individuals. These papers are listed in the bibliography presented at the end of this appendix.

The present geologic investigation was made principally in order to determine the geologic factors involved in the occurrence, movement, and storage of ground water in the water-bearing sediments of the Alameda County Area.

Physiography

The Alameda County Area comprises three different physiographic areas: the uplands of the Diablo Range, the intermontane valleys within the Diablo Range, and the San Francisco Bay depression. The uplands of the Diablo Range consist of fairly rugged mountains ranging in elevation up to 2,653 feet. The maximum elevation occurs near the southern limits of the county. Most valleys within the uplands are youthful and V-shaped. They have dissected a mature rolling surface, the remnants of which are found on high ridges. Soil cover is thin over much of the Diablo Range, but locally may be up to 15 or 20 feet in thickness.

The larger of the intermontane valleys, Livermore Valley, is a structural and topographic trough having an east-west axis. It is bounded on the west by Pleasanton ridge and on the east by the Altamont hills. San Ramon Valley occupies a narrow north-westward extension of Livermore Valley and is bounded on the west by the Calaveras fault (see Plate 7). Principal streams crossing the surface of Livermore Valley are Arroyo del Valle and Arroyo Mocho, which enter the valley from the south and flow only during the rainy season.

Surface drainage from Livermore Valley crosses the northern end of Sunol Valley on its way to the San Francisco Bay depression. Sunol Valley, also a structurally

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1/ Direct reference to a particular publication or report is indicated by means of a number in parentheses, for example, (20).

controlled intermontane valley, is much smaller than Livermore Valley. Castro Valley, the only other intermontane valley worthy of separate mention, is a small bowl-shaped valley northeast of Hayward.

In the Bay Plain the surface of the San Francisco Bay depression is divided into four physiographic units, the most important two of which are the alluvial area located adjacent to the uplands and the marshland area bordering the bay. The other two units comprise the Mission upland area which is located southeast of Irvington, and the Coyote Hills which rise out of the alluvial and marshland areas west of Newark.

The alluvial area is the location of most agricultural, industrial, and residential development in southwestern Alameda County. It is an area about 18 miles long in a northwest-southeast direction and from 1 to 6 miles wide. Its elevation ranges from about 5 feet on the west to over 200 feet on the east, and the average slope of its surface is about 20 feet per mile. The alluvial area is composed of coalescing alluvial cones, chief among which are, from north to south, the San Leandro, San Lorenzo, and Niles cones. Farther south it includes the Warm Springs alluvial plain, which is made up of coalescing cones from a number of small creeks. The major cones have been built by deposition from the three largest streams in the area, San Leandro, San Lorenzo, and Alameda Creeks. The Niles Cone, the largest of the three, was built up by deposition from Alameda Creek. The large cones have smaller cones superimposed on them near the hills, the outstanding example of which is the Dry Creek cone superimposed on the Niles Cone near Decoto.

The marshland area of San Francisco Bay borders the alluvial area on the west. It has a maximum width of about 3 miles, is very flat, and extends to an elevation of about 5 feet. The boundary between the marshland and alluvial areas is gradational in most places, but it approximates the westward limit of agriculture. Much of the marshland area contains evaporation ponds owned by salt companies; the remainder consists of sloughs, duck ponds, and areas with salt-tolerant plant cover.

The Mission upland area is an irregular-shaped terrace covering an area between 2 to 3 square miles southeast of Irvington. The rolling upland surface has a maximum elevation of about 780 feet and is dissected by valleys up to 125 feet in depth. Vegetation here is mostly grass, but some crops are grown in suitable areas. Sediments underlying the Mission upland are generally unconsolidated and relatively permeable.

Coyote Hills west of Newark are an elongated range of hills extending for a distance of nearly 4 miles in a northwesterly direction and having a maximum width of about 0.5 mile. Their maximum elevation is about 290 feet. Vegetation here is nearly all grass, but some oak and eucalyptus trees are present. The hills are composed of highly-fractured consolidated rock.

Geologic Formations

The geologic formations of the Alameda County Area are divided herein into water-bearing and nonwater-bearing groups. The water-bearing group consists of formations which yield water to wells of heavy draft in sufficient amount for irrigation, industrial, or similar uses. The nonwater-bearing formations also contain water; however, yield to wells is generally very low and the quality often poor. Thus these formations are of secondary importance with regard to ground water production. The areal distribution of geologic formations is shown on Plate 7.

Description of the Nonwater-Bearing Group

The nonwater-bearing group consists principally of marine sandstones, siltstones, and shales with some volcanic materials and continental sediments included. The oldest rocks are Jurassic in age and the youngest are Pliocene.

Jurassic. The Franciscan group and Knoxville formation of Jurassic age are not differentiated from each other on Plate 7. The Franciscan group consists of marine sandstone, shale, and some conglomerate, and includes some sedimentary and secondary chert, slightly altered basalt and diabase, serpentine, and a limited amount of schist. The knoxville formation consists of dark marine shale and some interbedded sandstone. It overlies the Franciscan group but occurs only in a small part of the area mapped. The maximum thickness of these rocks reported by Huey (8) in the Livermore Valley region is 15,000 feet.

Cretaceous. Cretaceous rocks consist primarily of marine sandstones, shales, conglomerates, and some siltstones. Lower Cretaceous rocks have been mapped as the Horsetown formation, Niles Canyon formation, and the Oakland conglomerate. Rocks of Upper Cretaceous age include the Moreno Grande, Panoche, Del Valle and Chico formations, as shown in the geologic columnar sections presented in Table 35. The maximum thickness of Cretaceous sediments reported in this area is about 18,000 feet.

Eocene. Eocene rocks consist of marine conglomerate, sandstone, shale and an occasional coal seam. They have been mapped by Huey as the Tesla formation (8), by Hall as the Tolman formation (20), and by Richey as the Tejon formation (25). Maximum thickness is estimated to be 2,000 feet.

Miocene. Miocene rocks consist principally of fossiliferous marine sandstones, shales, and conglomerates and include interbedded tuffs and coal seams. Miocene formations of the area are shown in the geologic columnar sections in Table 35.

TABLE 37

GEOLOGIC COLUMNAR SECTIONS
IN ALAMEDA COUNTY AREA

Age		Tesla Quadrangle (Huey, 1948)	Niles, Dublin, Livermore and La Costa Valley Quadrangles (Hall, 1958)	Mount Diablo Quadrangle (Richey, 1948) (South side of Mt. Diablo)	Hayward Quadrangle (principally from Lawson, 1914)
QUATERNARY	Recent and Pleistocene	Alluvium. Gravel, sand, and clay. Thickness 0-300 feet. Terrace gravel. Thickness 0-20 feet.	Alluvium (soil). Gravel, sand, and clay. Thickness 10-20 feet. Terrace gravel. Thickness 10-50 feet.	Alluvium.	Alluvium. Sand, gravel, and clay in alluvial fans grading toward San Francisco Bay into tidal clays. Thickness 0-700 feet.
		Unconformity	Unconformity	Unconformity	Unconformity
—(?)—	Plio-Pleistocene (Tertiary-Quaternary)	Livermore gravels. Continental gravel, sand, and clay. Thickness 4,000 feet.	Irvington gravels. Continental gravel, sand, silt, and clay. Thickness 300 feet. Livermore gravels. Continental gravel, sand, and clay. Thickness 3,000-4,000 feet.	Tassajara formation. Sand, clay, gravel, and tuff. Thickness 1,000 feet +.	Santa Clara formation.(in wells). Continental sand, gravel, and clay. Thickness 2,500 feet.
		Unconformity	Unconformity		Unconformity
TERTIARY	Pliocene	Buried beneath alluvium.	Orinda formation. Continental sand, gravel, and clay. Thickness 2,000-9,000 feet.	Green Valley formation. Clay, sand, gravel, and tuff of continental origin. Thickness 5,800 feet +. Diablo formation (Jacalitos). Marine sandstone and clay. Thickness 1,000 feet.	Orinda formation. Continental clay, sandstone, conglomerate, and limestone. Thickness 2,000 feet. Leona rhyolite. Surface flows and near-surface intrusions. Thickness 600 feet.
		Unconformity	Unconformity	Unconformity	
	Upper Miocene	Neroly formation. Sandstone and tuff. Thickness 2,000 feet +. Sandstone, conglomerate, and tuff. Thickness 50-700 feet. Cierbo formation. Sand, tuff, conglomerate, coal. Thickness 100-500 feet.	Neroly sandstone. Marine sandstone, siltstone, and shale. Thickness 500 feet. Cierbo formation. Marine conglomerate, conglometric sandstone. Thickness 750-2,000 feet. Briones formation. Marine sandstone and siltstone. Thickness 5,000 feet. Hambre sandstone and Tice shale. Marine in origin. Thickness 750-1,480 feet.	Neroly sandstone. Thickness 1,600 feet. Cierbo sandstone. Thickness 700 feet. Briones sandstone. Thickness 400 feet.	San Pablo formation. Thickness 2,000 feet Neroly sandstone. Blue sandstone and conglomerate. Cierbo sandstone. Massive gray sandstone. Marine. Briones formation. Massive fossiliferous pebbly gray sandstone. Marine. Thickness 3,000 feet.
		Unconformity			
	Middle Miocene	Oursan (?) formation. Sandstone, tuffaceous shales. Thickness 700 feet.	Oursan sandstone. Marine sandstone. Thickness 600 feet. Claremont shale. Marine shale. Thickness 700 feet. Sobrante sandstone. Marine. Thickness 200 feet.	Missing.	Monterey group. Several members. Includes sandstone, shale, siliceous shale, chert, and tuffaceous beds. Marine. Thicknese 3,400 feet.
		Unconformity	Unconformity	Unconformity	
	Eocene	Tesla formation. Marine sand and clay, brackish water sand, shale, and coal. Thickness 2,000 feet.	Tolman formation. Marine sandstone and conglomerate. Thickness 470-900 feet.	Tejon formation. Marine sandstone. Thickness 1,100 feet +.	Missing.
		Unconformity			Unconformity
CRETACEOUS	Upper	Moreno Grande formation. Sandstone, shale, and limestone concretions. Thickness 0-650 feet. Panoche formation. Sandstone, shale, and conglomerate. Thickness 10,000 feet +.	Del Valle formation. Marine sandstone and shale. Thickness 9,000 feet.		Chico formation. Marine sandstone, shale, and conglomerate. Thickness 13,500 feet.
		Fault			Unconformity
	Lower	Horsetown formation. Shale, sandstone. Thickness 0-500 feet.	Niles Canyon formation. Marine sandstone, siltstone, and shale. Thickness 7,500 feet. Oakland conglomerate. Marine conglomerate with shale interbeds. Thickness 1,400 feet.		Oakland conglomerate. Marine conglomerate, eandstone, and shale. Thickness 2,800 feet.
		Fault	Fault		Unconformity
JURASSIC (?)		Franciscan formation. Sandstone, shale, chert, conglomerate, pillow basalt, glaucophane schist, serpentine, diabase, and diorite-gabbro. Thickness 15,000 feet (?)	Knoxville formation. Marine shale. Thickness 500 feet. Franciscan group. Marine sandstone, shale, chert, metamorphic rocks, and associated igneous rocks. Thickness 6,000 feet +.		Knoxville formation Black marine ehale. Thickness 1,500 feet. Franciecan formation. Marine sandstone, shale, chert, and associated igneous rocks. Locally metamorphosed. Thickness 7,000 feet +.

Pliocene. Pliocene rocks consist principally of loosely consolidated continental sediments. They include conglomerate, sandstone, and shale with lenses of limestone and interbedded limey, concretionary, and tuffacaeous beds. They were mapped as the Green Valley formation by Harding (22) and as the Orinda formation by Hall (20). Vertebrate fossils have been found in several localities. The Leona rhyolite, consisting of surface flows and near-surface intrusions, outcrop at several localities, in the hills east of the Bay Plain.

Hydrologic Significance of the Nonwater-Bearing Group

In general, nonwater-bearing rocks form the boundaries of the ground water producing areas in Alameda County. They underlie sediments of the water-bearing group at depth and outcrop in the upland areas of the Diablo Range and the Coyote Hills.

Ground water in the nonwater-bearing group in the Alameda County Area is generally rather highly mineralized. This poor quality water is occasionally encountered in deeper wells drilled near the edges of Livermore Valley. It is probable that the higher mineralization is derived from Cretaceous and Tertiary marine sediments similar to those exposed in the uplands to the north and east. The Jurassic Franciscan rocks on the south probably do not contribute as much mineralization to waters with which they come in contact.

Although rocks of the nonwater-bearing group are relatively impermeable, it is likely that they transmit some water to the water-bearing sediments as subsurface flow through cracks and fissures. Some of the poor quality water occurring in the Livermore gravels and in the younger alluvium may have been derived from these older formations. Domestic water supplies are obtained from nearly all types of rocks in the nonwater-bearing group. Springs are the most common source of water. They occur chiefly along faults or fractures, and at contacts between different rock types. Shallow dug wells are found at most upland ranches that do not use spring water. Drilled wells might yield fair amounts of water in local areas where the geologic structure and rock types are favorable.

Description of the Water-Bearing Group

The water-bearing group consists of continental sediments of Tertiary-Quaternary and late Quaternary age. Three different formations occur in this area. Plio-Pleistocene (Tertiary-Quaternary) sediments in the Livermore and Sunol Valley areas are termed Livermore gravels. On the east side of the San Francisco Bay depression, sediments of similar age are termed the Santa Clara formation. Younger sediments of upper Pleistocene and Recent age are combined herein and called late Quaternary alluvium.

Tertiary-Quaternary. Sediments ranging from middle Pliocene to Lower Pleistocene age in the Livermore Valley ground water basin consist of up to 4,000 feet of gravel, sand, and clay composing the Livermore gravels. Limey and concretionary beds are fairly common in these sediments, and some tuffaceous beds are present near their base. These deposits evidently were laid down in lakes, swamps, and streams, but apparently not as alluvial fans.

Many of the sands and gravels are very well sorted and show prominent cross-bedding. The sands are fairly coarse-grained, and the larger grains therein are moderately well rounded. The gravels usually have a sand matrix. Isolated pebbles occur frequently in sands and clays. Pebbles of chert and sandstone are predominant in the Livermore gravels, but occasional pebbles of shale, schist, and igneous rock are found. Clay and silt usually occur as impurities in the sands and gravels.

The Livermore gravels are unweathered in most outcrops. Red clays in well logs south of the City of Livermore indicate that these sediments were weathered to moderate depths in that area. It should be noted that the term "clay," as used in this report, does not necessarily refer to true mineral clay but to material classified by well drillers as clay, which generally includes silt, and in places may include silty or clayey sand or gravel. The top of the Livermore gravels is buried by the younger late Quaternary deposits, and the age of the uppermost Livermore gravels, as determined from fossil and structural evidence, may be lower Pleistocene.

The Santa Clara formation is most prominent in the Mission upland area east of the southern end of San Francisco Bay. This formation, also considered to be of Tertiary-Quaternary age, has a maximum thickness of about 2,500 feet. It rests unconformably upon older rocks of the nonwater-bearing group. The Santa Clara formation probably underlies most of the late Quaternary alluvium in the Bay Plain, but no completely satisfactory criterion for differentiation of the two formations in well logs has been found.

In the Mission upland area the Santa Clara formation consists of medium to fine gravel, sand, silt, and clay and mixtures of these. These sediments are generally light blue when fresh, and yellow or brown when weathered. The material comprising these sediments consists of varied rock types from older formations in the area. Cross-bedding, scour and fill, lenticular shapes of beds, and extreme ranges in sorting point to stream deposition. The presence locally of vertebrate remains and the lack of marine fossils also indicate fresh water deposition.

The sediments are poorly indurated, containing very small amounts of cementing material. Well sorted gravels containing practically no fines occur in lenses, commonly up to 2 feet thick and 15 feet long. These lenses are extremely permeable. Where cropping out in gravel pits they can easily be traced as yellow streaks, due to iron coating on the individual pebbles.

The University of California has collected a large Pleistocene vertebrate fauna from the Santa Clara formation at the Bell sand and gravel quarry one mile southeast of Irvington. Fossils here occur about 800 feet below the exposed top of the formation in a sandy gravel bed. Limestone concretions have preserved some of the bones, while others are well preserved in loose sand. The age of these fossils is lower Pleistocene (26), and since they occur near the top of the exposed sediments, it is probable that some of the underlying Santa Clara formation is of upper Pliocene age.

Late Quaternary. Sediments of upper Pleistocene and Recent age are grouped herein as late Quaternary deposits. The deposits of both epochs were laid down after the middle Pleistocene orogeny and are practically flat lying. They were also deposited under conditions which did not change significantly between the epochs. As a result of their lithologic similarity, the upper Pleistocene and Recent deposits were not differentiated from each other in well logs.

In the Livermore Valley area, certain stream deposits in the small valleys north of Livermore Valley have yielded mammalian remains indicating an upper Pleistocene Age (29) and (26). Similar sediments are also found as scattered remnants overlying older formations as high as 1,500 feet above sea level on Mount Diablo (13).

In the Pleasanton area of Livermore Valley, a series of interbedded blue clay aquicludes and gravel aquifers form a pressure area. These aquicludes extend eastward across the Pleasanton fault to the vicinity of the Livermore fault where they and interbedded gravels form an extension of the pressure area. The blue clays in the Pleasanton pressure area occur as nearly continuous beds up to about 70 feet in thickness. At least four of these clay beds, separated by gravel strata, are present. A clay layer about 50 feet thick caps the entire pressure area. This area generally west of Pleasanton is known to have been covered by a shallow lake at times as recently as 1910. On this evidence, and the evidence of the lithology of these deposits, it is believed that the blue clays at depth were also deposited in lakes and swamps.

The lakes and swamps in the Pleasanton area probably were caused by depression of the block between the Calaveras and Pleasanton faults. As a result, the alluvium probably is deeper here than anywhere else in Livermore Valley. The alluvium probably is very thin west of the Calaveras fault.

In the southern part of Livermore Valley between the Pleasanton and Livermore faults, the alluvium contains a relatively large percentage of gravel. It has been deposited by the two largest streams in Livermore Valley, which enter this area from the south and east. The alluvium in this area is relatively thick and extensive. As would be expected, the smaller streams entering Livermore Valley from the north have deposited mostly finer-grained materials consisting of sands, silts, and clays. The alluvium in San Ramon Valley and in the area east of the City of Livermore is relatively thin. Weathered materials are not common in the late Quaternary alluvium of Livermore Valley. This is probably due to fairly rapid deposition, a high water table, or both.

In the Bay Plain, late Quaternary sediments include both alluvial and marshland deposits. The approximate surface contact between these deposits is shown on the geologic map, Plate 7, but at depth these deposits have mutually interfingered over a wide area, as the actual tidal area has fluctuated in the geologic past both to the east and west of the mapped contact. Both the alluvial fan and marshland deposits include Recent sediments and underlying deposits of upper Pleistocene age.

The alluvial materials which include gravel, sand, and clay and mixtures of the three were laid down on alluvial cones. In general, the coarse materials are found near the apexes of the alluvial cones and finer materials near San Francisco Bay. Clays are generally yellow or red in color and very silty. Blue clay is found northeast of the Hayward fault, probably representing lake and swamp sedimentation in sag ponds resulting from movement on the fault. The lagoon near Irvington is an existing sag pond. Sand is seldom reported in drillers' logs as such, because it usually has a high clay content and is thus reported as clay.

The marshland deposits are chiefly clays, with accompanying irregular and usually small lenses of sand and gravel. These clays may be distinguished from stream clays by their continuity and uniformity over large areas. Some well logs record shells occurring in these clays. Recent deposits have been observed during excavation for embankments, roads, and channels. These clays are blue-gray, contain locally abundant shell deposits, and show a very distinct stratification when dry. The stratification is formed by elongated lenses of silt up to 6 inches long and up to 0.2 inch thick within the clay. Similar tidal clays from the North Sea have been described in detail by Hantzchel (21).

Geologic Structure

The nonwater-bearing rocks of the Alameda County Area are folded into a series of anticlines and synclines and are cut by a number of prominent faults, as ndicated on Plate 7. The trend of the faults and the axes of the folds is generally orthwesterly.

escription of the Structural Features

The larger intermontane valleys are all structurally controlled, with the ossible exception of Castro Valley. Livermore Valley has developed in an east-west rending faulted syncline which is expressed very strongly in the Livermore gravels. he axis of this structure plunges gently westward and is cut off at the Calaveras fault n the west by the uplifted fault block of Pleasanton Ridge. The syncline is symmetrical; the south limb dips northward about 5 to 25 degrees, whereas the north imb dips about 60 to 80 degrees to the south. The syncline becomes more nearly ymmetrical in the eastern part of Livermore Valley, and variations in the general attern occur locally due to minor faulting and folding.

Sunol Valley lies largely between the Calaveras and Sinbad faults, and has robably resulted either from down-dropping of the block between the faults, or from rosion of relatively weak nonresistant rocks between them. San Ramon Valley has eveloped east of the Calaveras fault. Movement along this fault has uplifted the ills west of the valley. Castro Valley lies just east of the faults at the edge of he San Francisco Bay depression, but it is not known what effect movement on these aults has had in the formation of Castro Valley.

The principal faults in Livermore Valley are the Calaveras, Pleasanton, ivermore, and Parks faults. The Calaveras fault extends along the base of the ills on the west side of San Ramon and Livermore Valleys. The steep eastward face f Pleasanton Ridge is thus an eroded fault scarp. The fault is at least 90 miles ong, thus being one of the longer faults of the central Coast Range.

The Pleasanton fault trends about N. 25°W. and passes just east of the City f Pleasanton, as shown on Plate 7. It actually consists of two separate, nearly arallel faults in its northern part. The expression of these faults can be clearly een on aerial photographs taken in 1940 (Aerial Photograph No. BUT 341-105). The rea has since been leveled for construction purposes, and subsequent aerial photos o not show the fault traces. On the 1940 photos, the faults are strongly expressed by ligned gullies and saddles in the low alluvial terrace on the north side of the valley loor. A sag pond was observed in 1951 where the western-most fault crosses Dougherty oad on this terrace. From the edge of this terrace southward to U. S. Highway 50, the 940 photos show a marked change in shading at the faults due to differences in egetation of soil or both. Surface evidences of the faults disappear about one-half ile south of U. S. Highway 50. Farther south there is no surficial evidence of the faulting, but a marked difference in ground water levels across this fault defines its position to the southern edge of the valley. The ground water surface usually stands higher on the east side of the fault. Evidence from well logs, and the presence of wells of high yield very near the ground water break on both sides, indicate that the difference in water levels is not due to a pinching out of the water-bearing sands and gravels along the ground water break, but rather to a barrier effect at the fault itself, probably caused by offset of beds and/or the presence of gouge.

The Livermore fault trends about N. 40°W. and passes about one mile west of Livermore. Surface indications df the main fault may be seen as a low scarp extending for a distance of about 0.5 mile between the Pleasanton-Livermore road and Vallecitos Road. The scarp is west facing and varies in height up to about 15 feet. A marked soil change at the fault occurs south of the Pleasanton-Livermore road. East of the fault the soil is gravelly; to the west it is high in clay. North of the Pleasanton-Livermore road, the scarp is not present, but low, elongated ridges are found which have probably been caused by the fault. The physiographic evidence indicates that the Livermore fault is actually not a single break, but rather a zone of interrelated fractures. A marked difference in ground water levels occurs across the fault zone north of the Pleasanton-Livermore road. Water levels also indicate that a west branch of the fault exists just west of the main fault. Older sediments of the Livermore gravels have been faulted up between the Livermore fault and its west branch and assist in forming the barrier there.

The Parks fault trends in an east-west direction in the northern part of the Livermore Valley, but in the vicinity of the Pleasanton fault, its trend changes gradually to a northeast-southwest direction. There is no surface evidence present for locating this fault, but analysis of well log and water level data reveals a marked lithologic and hydrologic dissimilarity across it.

It is possible that the faults cutting the late Quaternary alluvium are limited in depth, perhaps extending into the Livermore gravels, but not into older formations. If so, these faults may pass into folding at depth.

The San Francisco Bay-Santa Clara Valley area is a depressed region between the Diablo and Santa Cruz Ranges. Depression of this region has occurred principally along faults near the edges of the basin, although some minor folds are associated with the faluts. In the Bay Plain of Alameda County, the principal structural feature is the Hayward fault. Movement along this fault has occurred during historic times. The strongest earthquake known to have been caused by movement on the Hayward fault occurred in 1869, and caused much damage to nearby structures. This fault extends along the foothills of the Diablo Range, generally at their base, except where it crosses the apex of the Niles Cone between Niles and Irvington. Surface evidences of the fault are numerous and well developed. Along the line of the fault between Niles and Irvington, several prominent elongated depressions 3 to 15 feet deep occur. Small elongated hills have been formed on either side of these sags in some places, with the larger occurring on the southwest side. These fault slivers stand 5 to 20 feet higher that the adjacent land. The land surface on the southwest side of the fault is about 3 to 15 feet higher than the general land surface on the northeast side. This difference in elevation has been caused by movement on the fault. Movement in the opposite direction (southwest side down) has been more prominent in the geologic past.

Forbes (18) describes a clay material formed by the Hayward fault exposed in a quarry near Niles. That exposure is now covered, but another nearby exposure was inspected during the field study for this bulletin. It was located in a Kaiser Aggregate Company gravel pit 0.5 mile southwest of Niles. The fault there consists of a vertical clayey sand dike about 1 foot wide that contained scattered pebbles and cobbles. Material composing this dike does not look like fault gouge but like fill material which might possible have been forced up from below in a saturated state, as it grades upward into undisturbed gravel. As seen in the exposure, the fault would appear to be a moderately effective deterrent to flow of ground water. It is likely that material in this fault may be ground into a true gouge at depth by movement on the fault. Such a gouge would be a more effective deterrent to movement of ground water than the material exposed near the surface. Material in the Hayward fault was also exposed for a short time in March 1951, about 1 mile northeast of Warm Springs, during construction of a new pipeline by the San Francisco Water Department. This exposure was located where the pipeline crosses the Mission San Jose-Warm Springs road about 15 feet to the south of the road. In the excavated ditch, the Santa Clara formation and some terrace gravels were exposed on the northeast side of the fault. On the southwest side of the fault a very small exposure of the Santa Clara formation was present, the remainder of the exposure being Recent alluvium. The Santa Clara formation here consists mostly of clay and fine sand beds with some thin calcareous lenses. The strata have a northeastward dip of about 30 degrees. The fault appears as a vertical clay dike about 3 feet wide and is composed of highly sheared and contorted clay that is probably derived from the Santa Clara formation. Near this clay, the bedded clay and sand of the Santa Clara formation are highly fractured and contorted, becoming less contorted away from the fault. No fracturing or contortion of sediments was observed farther than about 20 feet from the fault. Only about 5 feet of contorted Santa Clara formation was observed on the southwest side of the clay dike. This was overlain by Recent alluvium which also appeared to be slightly folded near the fault. The clay dike as exposed near Warm Springs probably is an effective deterrent to the lateral flow of ground water.

In the harder bedrock of the foothills, the Hayward fault may best be described as a zone of interconnected faults having a total width of one-eighth to three-eights mile. All the rocks within this zone are very severely sheared and contorted.

Another fault, the Mission fault, lies east of the Hayward fault in the southwestern part of the Alameda County Area. It occurs at the base of the foothills northeast of Mission San Jose and extends southeastward into the foothills.

In the Mission upland area, geologic structure, which is evident in the Santa Clara formation, consists of a low syncline plunging toward the north, as shown on Plate 7.

The Coyote Hills lie between the alluvial and marshland areas west of Newark. They are a ridge of impermeable rock that is surrounded and almost covered by sediments of the Niles alluvial cone. A fairly gentle slope of the bedrock surface beneath the alluvium occurs on the northeast side of the hills, as determined from well logs, but such data are lacking on the southwest side. It is possible that these hills have been formed in part by movement along the Silver Creek fault (Geologic section E-E', Plate 10). The bedrock of the Coyote Hills probably extends along the trend of the hills in a northwest and southeast direction beneath the alluvium and marshland deposits.

Hydrologic Significance of the Structural Features

Movement of ground water in the Livermore gravels exposed in the upland south of Livermore Valley is affected by the dip of these sediments which form one limb of a syncline or structural downwarp. Ground water tends to move down the dip of the sediments into the valley and then upward into the overlying Quaternary alluvium.

The Livermore, Pleasanton, and Parks faults in Livermore Valley, and the Hayward fault in the Bay Plain of the San Francisco Bay region, act as barriers to the lateral movement of ground water. It is not known whether a barrier effect is shown by either the Calaveras or Mission faults. The barrier effect of faults does not involve complete stoppage of water movement. Instead, movement is retarded either by formation of clayey gouge in the fault, or by offset of beds so that permeable eds on the side of the fault having higher water levels abut against beds of low ermeability on the other side. In either case, there is actually limited movement f water through the fault itself. In many cases, the fault is a more effective arrier at depth than near the surface, and such may well be the case with some of he faults of the Alameda County Area. Ground water builds up on the up-gradient ide of such faults and spills over the fault where it becomes an ineffective barrier t shallow depths.

Ground water moves southwestward through or over the Livermore and leasanton faults in Livermore Valley. The maximum water level differential in eep wells across the Livermore fault in the fall of 1959 was about 100 feet, and the aximum differential across the Pleasanton fault was about 50 feet. Water moves outhward through or across the Parks fault, and in May 1961, a water level ifferential of about 20 feet existed across this fault.

The Hayward fault forms a barrier to movement of ground water from the astern part of Niles Cone into its western part. The differential head built up ithin the late Quaternary alluvium across this fault in the fall of 1958 was pproximately 70 feet. The Hayward fault between Irvington and Warm Springs also cts as a deterrent to the westward movement of ground water from the Santa Clara ormation of the Mission upland area into the Warm Springs alluvial plain.

The Coyote Hills form a complete barrier to movement of ground water where hey rise above the elevation of the water surface. They prevent the direct movement f ground water between aquifers of the Niles Cone located east of these hills and quifers underlying San Francisco Bay.

Geologic History

Geologic history which has significance with respect to this investigation egins in middle Pliocene time. Table 37, Plate 10, and Plate 11 can be referred to fr a summary of the most important events which occurred during earlier periods.

From middle Pliocene through lower Pleistocene time water-bearing continental sdiments were being deposited in a large region which include most of the Alameda Cunty Area. The sediments were deposited in alluvial fans, lakes, swamps, and mrshlands. Deposition continued in valleys that slowly subsided. A maximum thickness o about 4,000 feet of sediments were deposited in the deeper parts of the Livermore Vlley area. These Plio-Pleistocene sediments make up the Livermore gravels in the Lvermore Valley area and the Santa Clara formation in the vicinity of San Francisco By. The San Francisco Bay depression probably first developed during late Pliocene time although actual flooding may not have occurred until after glaciers melted and freed large quantities of water to the sea.

During middle Pleistocene time the entire Coast Range underwent renewed faulting and folding. The Santa Clara formation between the Hayward and Mission faults was folded into a shallow syncline, and the Livermore gravels developed a synclinal structure in the Livermore Valley area. This period of mountain buckling was followed by a period of quiescence during which a mature, rolling topography was formed in the area east of the San Francisco Bay depression. Remnants of this erosion surface now make up the rather level ridge tops surrounding Livermore Valley.

In upper Pleistocene time uplift of the region was renewed, and large valleys formed. Ancient Livermore Valley was the largest of these. The drainage outlet of Livermore Valley at this time may have been northward through the ancient San Ramon and San Ygnacio Valleys in to what is now Suisun Bay (13).

The filling of Livermore Valley with sediments began in late Pleistocene times. During the depositional period, the valley surface was distorted by faulting, so that some parts were raised and others lowered. Late Quaternary sediments then filled Livermore Valley and now are the main source of ground water supply.

Originally, surface drainage out of Livermore Valley probably was northward through San Ramon Valley, At some time after the filling of Livermore Valley began, the drainage outlet assumed its present course to Alameda Creek. The reasons for this change are obscure, but probably involve vertical movement on the Calaveras fault and the capture of the Livermore Valley drainage by a tributary of ancient Alameda Creek. It is possible that the drainage outlet of Livermore Valley alternated between its present position and San Ramon Valley during deposition of the alluvium. The changing of the drainage could easily have been controlled by movement along the Calaveras fault, alternately forming a surface barrier to Arroyo de la Laguna by uplift south of Pleasanton and then destroying the barrier. Destruction of the barrier could also have been accomplished by erosion. This hypothesis would explain the fact that the blue clays and gravels of the western part of Livermore Valley occur in distinct and widespread layers, indicating major and rapid changes in depositional environment.

Deposition of late Quaternary alluvium is still continuing. Movement on the major faults has continued into recent times, and the alluvium of Livermore and Sunol Valleys and the San Francisco Bay region has been disturbed where cut by these faults. Deposition in the San Francisco Bay region has probably been controlled to some extent by fluctuations in sea level, as indicated by the widespread occurrence of several gravel beds overlain by clay. Each of these sequences of gravel overlain by clay probably represents a rising stage of sea level, most likely closely related with the melting of Pleistocene continental glaciers.

Description of Principal Ground Water Producing Areas

The principal ground water producing areas in the Alameda County Area which were studied during this investigation include Livermore and Sunol Valleys, and the portion of the San Francisco Bay region within the area. In conformance with the hydrologic subdivisions of the Alameda County Area in the main body of this bulletin, these areas have been designated "Livermore Valley," "Sunol Valley," and "Bay Plain." These areas have been subdivided further into smaller units based upon the presence of faults or other geologic conditions that affect the occurrence and movement of ground water (see Plate 7).

Livermore Valley

For the purpose of this investigation, only the valley floor portion of the large Livermore Valley ground water basin as defined in Bulletin No. 84, "Recommended Water Well Construction and Sealing Standards, Alameda County" (11) was studied in detail. It encompasses an area of approximately 65 square miles. Limited data were available concerning the occurrence and movement of ground water in the Livermore upland. As a result, they received only a cursory study.

Occurrence of Ground Water. Ground water in the Livermore Valley occurs in the Tertiary-Quaternary Livermore gravels as well as in the overlying late Quaternary alluvium. The Livermore gravels outcrop extensively in the upland area south of Livermore Valley and underlie the alluvium at depth.

The Tertiary-Quaternary Livermore gravels average about 2,000 feet in thickness over approximately 95 square miles, under and adjacent to the alluvium in Livermore Valley. Since the alluvium averages only about one-tenth of this thickness, the available storage capacity of the Livermore gravels is probably considerably greater than that of the alluvium. However, the alluvium, being considerably more permeable, is the principal water-producing deposit. In general, ground water is produced from wells penetrating alluvium only, but in the eastern part of Livermore Valley and in San Ramon Valley, several wells obtain water only from the Livermore gravels. Early in 1950, fifteen irrigation wells were known to derive water only from the Livermore gravels. Without these deep wells, irrigation in San Ramon Valley and in part of eastern Livermore Valley might not be possible, since the yield of most wells in the late Quaternary alluvium in those locations is small. It is expected that an increasing number of deeper wells will be drilled into the Plio-Plistocene sediments in the future, thus increasing their importance as a source of ground water.

Detailed studies of ground water conditions in the Livermore Valley have been made in other investigations (10, 11, 13, 27). The floor of Livermore Valley includes five of the six subbasins which make up the complete Livermore Valley ground water basin. The subbasin excluded is the Livermore upland. Probably the most important of the subbasins included in Livermore Valley, with respect to production of ground water, are the Santa Rita and Pleasanton subbasins. The remainder are the Parks, San Ramon, and Livermore subbasins.

The arrangement of aquifers (permeable gravel or sand and gravel strata) and aquicludes (relatively impermeable fine-grained strata) in the alluvium of Livermore Valley is shown in the Geologic sections on Plate 11. Aquifers were found to be consistently the same beneath nearly all of the subbasins west of the Livermore fault (10).

The upper aquifer, as shown on Plate 11, has a greater areal extent than the deeper aquifers, especially in the San Ramon subbasin, where it alone is present. Vertical movement of surface or near surface water into the upper aquifer is restricted or prevented by the thick, relatively impermeable upper aquiclude which overlies it. Interchange of water between aquifers is restricted or prevented by continuous clay layers and so each aquifer is a relatively independent hydrologic unit.

In the Santa Rita subbasin well log and water level data indicate that three aquifers exist (Section C-C' Plate 11). Elevation of the water surfaces is shown and illustrates the water level differential occurring between aquifers. Ground water in the upper aquifer is unconfined (not under pressure) as an air gap exists within the aquifer between the water surface and the overlying aquiclude. The water surface in wells producing from this aquifer represents the water table. Water in the deeper aquifers is confined, and the water surface in deeper wells perforated in each of these aquifers stands above the overlying aquiclude and represents a pressure (piezometric) surface.

The water table within the upper aquifer in the Santa Rita subbasin stands at an elevation higher than that of the two pressure surfaces and of these, the piezometric surface of the second aquifer stood about 25 feet higher than that of the third aquifer in May 1961. The pressure surface of the third aquifer was observed only in the water levels of wells located a short distance west of the Livermore fault which are known to be perforated solely within the deeper aquifers.

Wells in the Pleasanton subbasin are generally deeper than those in the remainder of Livermore Valley, and they indicate that a fourth aquifer occurs below a depth of 250 feet. A narrow arm of late Quaternary alluvium extends south from the main part of the subbasin into the narrow canyon of Arroyo de la Laguna southwest of Pleasanton. Steep walls rise abruptly on both sides of the relatively flat surface of the alluvium that forms the canyon floor. The alluvium here has filled an ancient V-shaped cut eroded in the past to a depth of about 150 feet in the nonwater-bearing rocks composing the east well of the present canyon. Evidence from test hole drilling and well log data show that the deep aquifers present in the main Pleasanton subbasin are missing beneath the upper aquifer in the narrow canyon area (10).

All aquifers in the Pleasanton subbasin contain ground water confined under pressure. Nearly all wells are perforated in more than one deep aquifer. As a result, no significant water level differential between these aquifers has been observed. The water surface in the upper aquifer was approximately 30 feet higher than that in deeper aquifers during May 1961.

There are limited data with respect to the occurrence of ground water in the Parks subbasin. There are few wells, and the known poor yield of those present indicates that the sediments are of low permeability. Well logs describe these sediments as sandy clay with occasional sand beds. The sediments either have been derived by erosion from the pre-Livermore fine-grained Pliocene deposits exposed in the hills to the north or are a southern extension of these hill sediments overlain by a thin cover of younger alluvium. Water levels in wells in the Parks subbasin north of the Parks fault were 20 feet higher than in wells of equal depth in the Santa Rita subbasin immediately south of the fault. The Parks fault evidently acts as a barrier to the movement of ground water. These data indicate the relative difference between the occurrence of ground water in the Parks and Santa Rita subbasins and the degree of isolation between them caused by the Parks fault.

There are limited data with respect to subsurface conditions in San Ramon subbasin. The upper aquifer here is capped by the upper aquiclude and contains confined ground water. It is the principal ground water producing aquifer in that portion of the subbasin located south of U. S. Highway 50. Pumping tests indicate it has a coefficient of permeability of approximately 240 gallons per day (10). Several deep wells located in the northern part of the area produce substantial quantities of ground water (over 500 gallons per minute).

In the Livermore subbasin alluvium generally is not over 100 feet thick, and ground water is produced largely from the underlying Livermore gravels. Permeability of the sediments in this subbasin is generally lower than those penetrated by wells in the Santa Rita subbasin; thus yields to wells are less. Ground water in the alluvium is probably essentially free while that in the Livermore gravels is confined.

Movement of Ground Water. Ground water replenishment to aquifers in the Livermore gravels probably occurs in areas of outcrop south of Livermore Valley. In this area the synclinal structure of the Livermore gravels acts as a catchment basin. Water from precipitation and stream flow infiltrates the exposed premeable deposits and, after reaching the water table, moves northward down the prevailing dip of the sediments. It probably becomes confined by clay layers within a relatively short distance, and then migrates into aquifers underlying Livermore Valley. Some of this water undoubtedly moves from aquifers occurring in the Livermore gravels upward into the overlying Quaternary alluvium.

In the subbasins included within Livermore Valley, ground water moves west from the Livermore subbasin into the Santa Rita subbasin, thence into the Pleasanton subbasin. Ground water in the San Ramon and Parks subbasins moves south, and ultimately collects in the Pleasanton subbasin. Within the Pleasanton subbasin, ground water is either withdrawn by pumping (as at the present time); or, if allowed to accumulate to a high enough head (as it has in the past), will escape from the upper aquifer as underflow down the canyon of Arroyo de la Laguna; or will migrate upward through the upper aquiclude via artesian wells and effluent seepage to support surface flow.

Recharge to the upper aquifer in the Livermore subbasin is principally by infiltration and percolation of surface water from Arroyo Las Positas and Arroyo Mocho. Deeper aquifers occurring in the Livermore gravels are probably recharged by the lateral percolation of water that has infiltrated permeable deposits in the upland to the south.

Ground water in the Livermore subbasin moves in a general westward direction toward the Santa Rita subbasin (Plate 5). The Livermore fault, definitely a ground water barrier, restricts the lateral movement of ground water from the Livermore subbasin into the adjacent Santa Rita subbasin. In May 1961, the pressure surface in deep wells was nearly 90 feet higher on the east than on the west side of the fault. However, shallow wells on the west side had water levels standing at very nearly the same elevation as the pressure surface east of the fault. The fault zone may present much less of a barrier to the westward movement of ground water in shallow aquifers than in deeper confined aquifers.

Recharge to aquifers in the Santa Rita subbasin occurs principally by infiltration and percolation of surface water from Arroyo del Valle in the alluvial gravels in the southern portion of the subbasin and in the Livermore gravels in the upland area to the south. Significant subsurface inflow of ground water occurs through the Livermore fault from the Livermore subbasin. In the area of the Livermore fault, the confining aquiclude appears to be discontinuous and surface water can infiltrate to ground water in the upper aquifer. Recharge by movement of ground water across the Livermore fault occurs principally during dry seasons when the water level differential across the fault is greatest.

The general movement of ground water in the Santa Rita subbasin is westward into the Pleasanton subbasin. To the north between the Livermore and Pleasanton faults, both the shallow unconfined and deep confined ground water moves westerly through the Pleasanton fault into the aquifers of the Pleasanton subbasin. The main Pleasanton fault and the east branch act as barriers to the westward moving ground water so that the water levels in the wells east of the faults are higher than those to the west.

The principal movement of confined ground water through the Pleasanton fault probably occurs in the central portion of the subbasin, just north of the branch point, where the fault must be more permeable at depth. However, upper aquifer ground water moves more readily through the southern portion of the fault south of the branch point. Apparently this is the most permeable area in the shallow portion of the fault. The total drop in water levels in deep wells westward across the fault was 25 feet in May 1961 (10).

Recharge to aquifers underlying San Ramon subbasin is derived principally by infiltration and percolation of surface water from South San Ramon Creek to the north where the upper aquiclude is absent or discontinuous. Movement of ground water in the upper aquifer is southwest toward the Parks fault, a ground water barrier that restricts the movement of ground water into the Pleasanton subbasin. The water level differential across this fault in May 1961 was approximately 12 feet, with the higher levels being on the northern side. Differential water levels indicate the probable existance of a concealed fault immediately west of South San Ramon Creek (Alamo Canal) which restricts the lateral flow of ground water. Water levels are higher on the west side of this fault (10).

Recharge to aquifers in the Parks subbasin is probably from infiltration and percolation of precipitation and surface water from the small creeks debouching onto Livermore Valley from the north. Ground water movement in the eastern part of the subbasin is westward, parallel to the Parks fault, a ground water barrier. In the western part of the subbasin, however, restricted movement of ground water over or through the fault occurs. The small quantity of water moving through this fault probably recharges only the upper aquifer of the Santa Rita subbasin to the immediate south(10).

In the Pleasanton subbasin there are so few shallow wells existing that a reliable determination of the elevation of the water surface and the direction of ground water movement in the upper aquifer was not possible. The water surface elevation in it is known to be higher than the deep piezometric surface at the western and northern edges of the subbasin and it appears to slope eastward toward the southern portion of the Pleasanton fault. A depression seems to exist in the upper aquifer water surface near the southern portion of the Pleasanton fault that perhaps indicates movement of upper aquifer ground water downward into deeper aquifers along the fault zone, through discontinuities in the aquicludes in this area, or through Livermore gravels beyond the extent of the underlying aquicludes (10).

The Pleasanton subbasin, and thus Livermore Valley, evidently are a part of a "closed" ground water basin. Under the presently existing conditions, there is essentially no subsurface outflow from this basin. Deep aquifers do not extend into the narrow part of the canyon of Arroyo de la Laguna, and ground water movement in shallow aquifers in this canyon is northward into the main valley (10).

Sunol Valley

Sunol Valley, situated in the central part of Alameda County immediately south of Livermore Valley, includes only the Sunol subbasin of the Sunol Valley ground water basin (see Plate 7). Additional subbasins within the ground water basin are Vallecitos, La Costa, and Sunol upland subbasins. Tertiary-Quaternary Livermore gravels and older, consolidated, nonwater-bearing rocks outcrop in the upland areas bordering the valley and underlie the late Quaternary alluvium in the valley.

Occurrence of Ground Water. Ground water in Sunol Valley is produced principally from the Quaternary alluvium which probably has a maximum thickness of about 160 feet. The Livermore gravels, which outcrop in the upland area and probably underlie the Quaternary alluvium, are water-bearing; but there are no known wells that obtain large quantities of water from these sediments. Thickness of the Livermore gravels that underlie the alluvium is unknown.

Ground water in the alluvium is probably unconfined, while water in the underlying Livermore gravels is probably confined.

Movement of Ground Water. Ground water in Sunol Valley is probably replenished principally by infiltration and percolation of precipitation, stream flow, and water applied for irrigation and other uses on the Quaternary alluvium of the valley. It moves in the general direction of the topographic slope from the areas of recharge to the areas of discharge. Discharge is by effluent flow into Alameda Creek and by evapo-transpiration during periods of high water levels, and by pumping.

Bay Plain

The Bay Plain, situated in the eastern portion of the San Francisco Bay depression, is an important part of the large Santa Clara Valley ground water basin. It encompasses an area of approximately 190 square miles.

Occurrence of Ground Water. Quaternary alluvium and the Tertiary-Quaternary Santa Clara formation are the principal water-bearing deposits in the Bay Plain (see Plate 7). The Santa Clara formation outcrops only in the Mission upland southeast of Irvington but probably underlies the alluvium and marshland deposits of the Niles, San Leandro and San Lorenzo alluvial cones.

Fine-grained, tidal marshland deposits are of particular importance with respect to the occurrence and movement of ground water in the Bay Plain. During the geologic past, the contact between marshland deposits and stream-laid alluvium has fluctuated to the east and west of the present line, resulting in interlayering of relatively impervious marshland clays and permeable alluvial sands and gravels (Plate 10). These interlayered deposits form a series of confined aquifers beneath the greater part of each alluvial cone.

Ground water is produced principally from Quaternary alluvium. Wells in the Bay Plain yield an average of from 200 to 600 gallons per minute, with a maximum reported yield of over 2000 gallons per minute.

The Bay Plain previously has been subdivided into seven ground water subareas (Plate 7). Each subarea is bounded by faults or other geologic structures, or by conditions that affect the occurrence or restrict the movement of ground water between adjacent subareas (11, 12).

As the Niles alluvial cone is the area of greatest agricultural development in the Bay Plain at the present time, the most important of these subareas are the confined ground water area of the Niles Cone, the forebay area for the Newark aquifer of this cone, and Stivers alluvial area. The ramaining subareas are: the confined ground water areas of the San Leandro and San Lorenzo cones, Warm Springs alluvial plain, and the Mission upland.

The confined ground water area of the Niles Cone has been studied in detail as it has been severely affected by the intrusion of sea water. Aquifers have been named and delineated in a previous report (12). From the surface of the confined ground water area of the Niles Cone to a depth of approximately 400 feet, a number of aquifers occur as distinct hydraulic units. The Newark aquifer extends to a maximum depth of about 175 feet, the Centerville aquifer occurs between 190 and 240 feet, and the Fremont aquifer is found between approximate depths of 250 and 300 feet (Geologic section G-G', Plate 10). These aquifers are relatively thick and extensive and are separated from one another and confined by blue clay layers. The gravel layers become thinner and contain more fine-grained materials with increasing distance from the point where Alameda Creek debouches from Niles Canyon onto the Bay Plain. All of these aquifers are confined and their confining layers extend westward beneath the floor of San Francisco Bay. Confined aquifers below a depth of 400 feet are believed to be relatively continuous across the San Leandro, San Lorenzo, and Niles cones and the Warm Springs alluvial plain. There are three or more aquifers in the Niles Cone below this depth, each of which appears to be a separate hydraulic unit.

Two minor perched or semiperched aquifers overlie the clay layer confining the Newark (upper) aquifer of the Niles and San Lorenzo confined ground water areas. One of these minor aquifers is located in the Valle Vista area and the other near Newark. The area containing perched water near Valle Vista overlaps the boundary between the Niles and San Lorenzo cones (Plate 7). It is described in subsequent paragraphs regarding the San Leandro and San Lorenzo subareas. The aquifer near Newark overlies the clay layer confining the Newark aquifer to an unknown extent and yields limited quantities of water to wells.

The extent of the area considered to be the forebay or replenishment area for the Newark aquifer of the Niles Cone is based on data obtained from well logs and from logs of test holes. Wells within this area are generally less than 150 feet deep and penetrate coarse gravels and sands interspersed with thin, discontinuous lenses of yellow clay. As well log data are limited, the extent of the aquiclude underlying the Newark aquifer is unknown in this area. It is possible that a portion of this area contains no extensive clay layers and may also be the forebay for deeper confined aquifers underlying the Niles Cone.

Stivers alluvial area is separated from the confined ground water area of the Niles Cone and the forebay area for the Newark aquifer of the Niles Cone by the Hayward fault, a recognized barrier to the lateral movement of ground water. Much of this alluvial area, having no extensive clay layers, contains free ground water.

In the San Leandro and San Lorenzo alluvial cones, water-bearing deposits extend to a maximum depth of about 1,000 feet and ground water generally occurs under confined conditions. Aquifers, or water-bearing sand and gravel layers, in these two northern cones were not studied in the same detail as those in the Niles Cone to the south; however, several aquifers are known to occur. They consist of irregular lenses of sand and gravel which are difficult to correlate over any great distance. Although these aquifers were delineated to some extent, they were not named. They are thinner and less extensive than those in the adjoining Niles Cone. Water wells in the San Leandro and San Lorenzo cones are drilled to considerably greater depths than in the Niles Cone and generally are perforated in more than one aquifer or are constructed with gravel envelopes.

There appears to be an upper confined aquifer occuring between the land surface and a depth of about 150 feet in each of the two northern cones, another between 150 and 250 feet in depth, and a third at a depth of about 300 feet (Geologic section G-G' Plate 10). For identification, these aquifers are considered to be "equivalent to" the Newark, Centerville, and Fremont aquifers of the Niles Cone.

There is a minor perched aquifer in the Valle Vista area, between the communities of Mt. Eden and Decoto (see Plate 7). This aquifer overlies the clay layer that confined the Newark (upper) aquifer and contains unconfined ground water. Only a few domestic wells, generally less than 50 feet in depth, tap this aquifer. Water-bearing materials are principally sand and yield relatively small quantities of water to wells.

The Warm Springs alluvial plain is underlain by finer-grained sediments than the alluvial cones to the north. Water wells penetrate thick sections of brown and yellow clay, and sandy clay which contain thin layers of water-bearing sand and fine gravel. Ground water probably is confined. Wells 200 or more feet in depth generally are perforated continuously from a depth of about 50 feet to the bottom of the well.

The Mission upland area is located on the eastern side of the Hayward fault. It is separated, hydrologically, from subareas to the west by this ground water barrier fault. Ground water probably occurs under confined conditions as thick, extensive layers of fine-grained deposits are known to occur. Some deep wells yield up to 400 gallons per minute, but most wells have a lower yield. Drillers perforate wells adjacent to gravels but not sands in this subarea.

<u>Movement of Ground Water</u>. The slope of the water surface in wells is indicative of the direction of ground water movement. Accordingly, concerted efforts

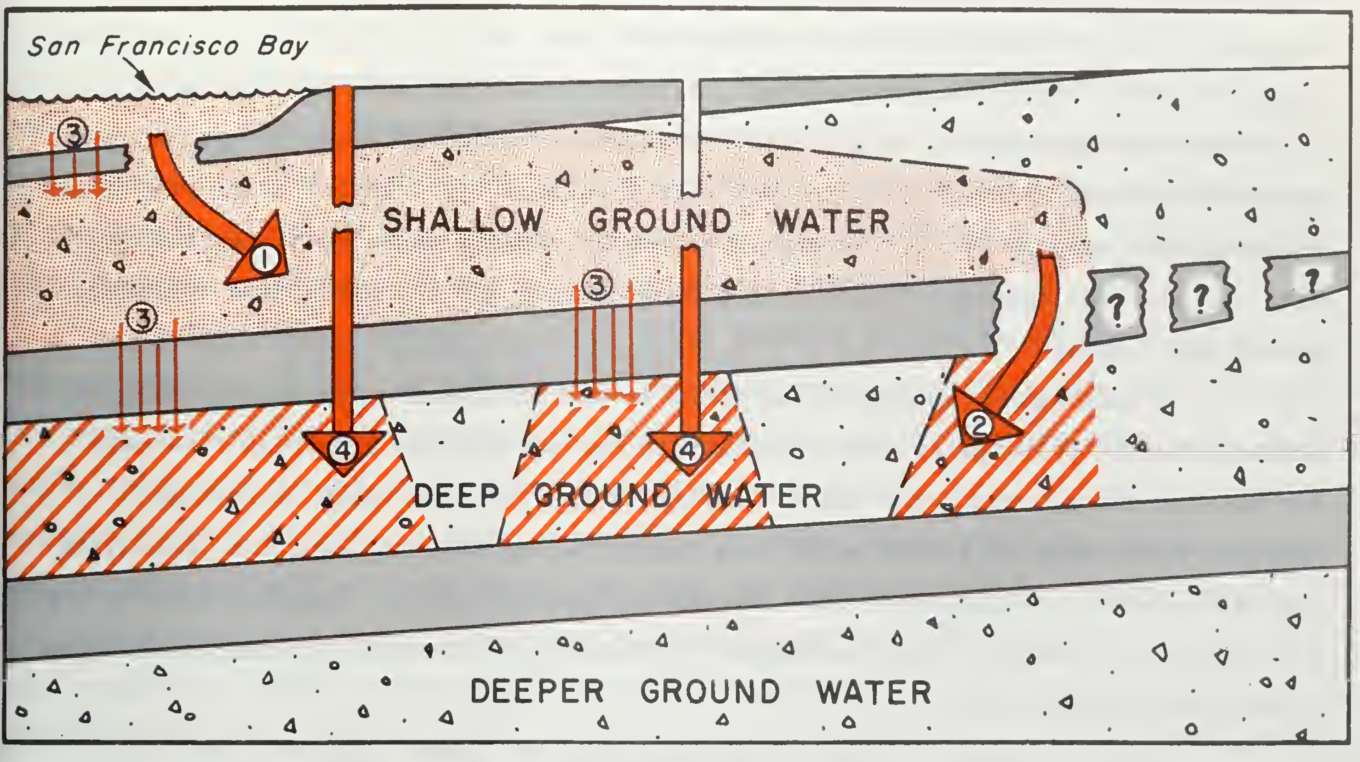
were made to obtain records of water level measurements made in the past. To provide a uniform basis for comparison, all water level observations made during this study were converted to the mean sea level datum established by the United States Coast and Geodetic Survey for the San Francisco Bay area.

Records of ground water level measurements in the Bay Plain began as early as the 1890's. Water Supply Paper 345-H of the United States Geological Survey (34), and records of the East Bay Municipal Utility District and the Alameda County Water District provide the most complete data.

Under natural conditions, ground water surfaces sloped toward San Francisco Bay. In wet years natural springs flowed in some areas near the bay, and ground water probably moved upward into the salt water of the bay from the underlying aquifers.

Ground water recharge to aquifers underlying the Niles Cone occurs at the apex of the cone in the vicinity of the Niles district of Fremont. The Newark aquifer, and possible deeper aquifers, are probably recharged by infiltration and percolation of streamflow from Alameda Creek in the forebay area west of the Hayward fault. It is also probable that substantial quantities of ground water move through the fault barrier from Stivers alluvial area to provide recharge to aquifers underlying the Niles Cone.

Previous to 1913, water levels were above sea level in the Niles Cone. Since that date, however, water levels have been lowered below sea level by continuous overdraft. In 1924, due to almost total lack of recharge of the Niles Cone from Alameda Creek, water levels fell from 30 to 40 feet below sea level. Consequently, intrusion of saline bay water into the Newark aquifer of the Niles Cone began, although some shallow wells near Alvarado showed quality degradation as early as 1920 (43). Water levels continued to drop from 1924 to 1936. During 1936 to 1943 the water levels recovered as a result of above-normal rainfall, however, from 1943 to the present time ground water levels again have been lowered steadily. Lines of equal elevation of ground water (ground water contours) for the Newark and Centerville aquifers of the Niles Cone during the spring of 1961 are shown on Plate 5. During this time the water surface in the Newark aquifer sloped landward toward a trough in the vicinity of Centerville. The water surface in the Centerville aquifer was below that in the Newark aquifer and sloped bayward from the apex of the Niles Cone. In the Centerville area, differential head between the Newark and Centerville aquifers typically varied from about 10 feet in March to over 40 feet at the height of the pumping season in late summer. Aquifers lying below the Centerville aquifer indicated pressure levels almost identical with those of the Centerville aquifer, although hydraulic connection probably exists only in the forebay area.



LEGEND

Clay　　Sand and Gravel　　Salt Water

NOTE

1. Direct movement of bay waters through natural "windows".
2. Spilling of degraded ground waters.
3. Slow percolation of salt water through reservoir roof.
4. Spilling or cascading of saline surface waters or degraded ground water through wells.

Figure 6.

POSSIBLE MEANS FOR ENTRY OF SALT WATER INTO GROUND WATER

Ground water recharge in the Stivers alluvial area probably occurs principally by infiltration of stream flow from Alameda Creek and by subsurface percolation from the Mission upland area to the southeast. Water levels in this subarea, which is situated east of the Hayward fault barrier, historically have been above sea level as the lateral movement of ground water out of this subarea is restricted by this barrier fault. The average water level differential across the Hayward fault was about 30 feet in 1950 with a maximum differential of 70 feet being recorded near Alameda Creek. Ground water probably moves eastward across the fault into the adjacent forebay area for the Newark aquifer and the Niles Cone confined ground water area.

Ground water recharge to aquifers in the San Leandro and San Lorenzo cones probably results principally from infiltration and percolation of stream flow near the apex of these cones. The exact location of the recharge areas is unknown. Subsurface movement of ground water from Castro Valley into the aquifers underlying the San Lorenzo cone may also occur through the Hayward fault. Aquifers below a depth of 400 feet are probably also recharged by percolation of water from deeper aquifers underlying the Niles Cone.

Lines of equal elevation of ground water in "upper" aquifers and in composite "deeper" aquifers in the Bay Plain for spring of 1961 are shown on Plate 5. Water level contours from the composite aquifers obtained under static conditions probably are reliable enough to indicate the general direction of ground water movement.

During the spring of 1961, water levels in upper aquifers of the San Leandro and San Lorenzo cones sloped from elevations of about 30 feet above sea level at the foothills south of Hayward, to sea level near the bay (see Plate 5). At the same time water levels in deeper aquifers ranged from about 30 feet above sea level near Hayward to over 80 feet below sea level in the central and southern portions of the San Lorenzo cone. At these latter localities, water levels in the deeper aquifers appeared to be the lowest of any in the San Leandro and San Lorenzo cone subareas.

In the Warm Springs alluvial plain, recharge to aquifers occurring above a depth of 400 feet probably results principally from subsurface movement of ground water through the Hayward fault barrier from the Mission upland area to the east. Recharge to deeper aquifers, which are probably in hydraulic continuity with deeper aquifers underlying the Niles, San Lorenzo, and San Leandro cones, is probably from subsurface percolation from the Niles Cone as well as movement through the Hayward fault to the east. Subsea water levels occur only in the southeastern portion of the Warm Springs alluvial plain.

In Mission upland area, situated east of the Hayward fault barrier, aquifers are probably recharged by infiltration and percolation of water from the small intermittent streams crossing this area. Movement of ground water is probably westward into aquifers underlying Warm Springs alluvial plain and northeastward into Stivers alluvial area. Water levels in 1949 and 1950 were from 5 to 60 feet higher on the northeast side of the Hayward fault in the Santa Clara formation, and the ground water gradient indicated a westerly movement of ground water (13).

Saline Water Intrusion. Ground water supplies in the Bay Plain have been increasingly degraded by the intrusion of sea water over a period of some 40 years (43). At first, this effect was restricted to shallow wells. As the shallow wells were abandoned, deeper wells were placed in service and provided good quality water for about a quarter century. During the past 15 years, however, salt water has intruded the deeper gravels and has affected many of these wells. By 1928, the Newark aquifer in a large portion of the area bayward from Fremont Boulevard contained water that was unsuitable for irrigation use. About this time, ranchers began drilling wells about 200 feet in depth into the Centerville aquifer. This aquifer is protected from the Newark aquifer by a thick layer of clay. Because of this new source of water supply, the seriousness of incipient salt water intrusion was not fully recognized. During 1959 the areal extent of the degradation in the Centerville aquifer, was approximately 3,000 acres and increasing. The principal degradation of the Fremont aquifer, which underlies the Centerville aquifer, began at this time, and by late 1961, extensive areas of the deeper aquifers were degraded.

Intrusion of saline bay water into the Newark aquifer and the subsequent movement of degraded ground water from this aquifer into deeper aquifers containing usable ground water was studied in a previous investigation (12). Possible means of entry of saline water into aquifers underlying the Niles Cone are shown in Figure 6 entitled "Possible Means for Entry of Salt Water Into Ground Water" (Page 177). It is seen that there are probably three natural paths for subsurface movement of salt water into ground water reservoirs. The fourth path is manmade. It permits leaking or cascading of saline surface or ground water through wells. The shallow ground water reservoir corresponds to the Newark aquifer and the deeper reservoirs correspond to the Centerville and Fremont aquifers.

The most probable area of entry of saline bay water into the Newark aquifer is beneath the deepest part of the tidal channel in the vicinity of Dumbarton Point. Typically, bay muds and blue clay with a total thickness of about 50 feet overlie the Newark aquifer. Meandering tidal currents have eroded this material to a thickness of about 5 feet forming a mud "window" which extends over a width of about 2,500 feet for an undetermined distance. It is almost certain that, during maximum tidal currents, the bottom scour extends through the mud and exposes the gravels of the aquifer.

Some salt water may have entered the Newark aquifer through breaches in the clay layer underlying the tidal flats. At one time springs existed along the western edge of Coyote Hills. Those channels through which spring water formerly flowed upward may now carry salt water downward. Pier and piling holes and abandoned water wells may also form breaches. The quantities of flow involved are probably relatively minor.

Prior to the time when water levels in the aquifer were drawn below sea level, fresh ground water must have migrated upward through the thin mud blanket. Since the 1920's, when ground water levels assumed a landward gradient, sea water has moved downward and eastward into portions of the Niles Cone area.

Subsequent to sea water intrusion in the Newark aquifer, salinization progressed into deeper aquifers. The salt water was found to have three possible means of access into deeper stratas:

1. Spilling of degraded ground waters over the inland edge of the clay layer separating the Newark and deeper aquifers.
2. Percolation of degraded ground water through the clay layer separating the Newark and deeper aquifers.
3. Leaking or cascading of saline surface or degraded ground water into deeper aquifers through wells improperly constructed or inadequately sealed when abandoned.

Although the eastern extent of the aquiclude underlying the Newark aquifer was not determined, previous investigative work indicated that up until July 1959 there probably has been no spilling of degraded water over the inland edge of the clay layer underlying the Newark aquifer and into deeper aquifers. As saline water in the Newark aquifer has migrated further inland since that time, it is possible that this type of interaquifer exchange of saline water is not occurring. Further information should be obtained to determine the integrity of this vital clay layer.

Data obtained from laboratory and field tests to determine leakage through the clay layer separating the Newark and Centerville aquifers indicated that aquiclude leakage could account for a significant portion of the degradation in the Centerville aquifer as long as a water level differential existed between the aquifers.

In order to evaluate the extent to which salt water intrusion in the enterville aquifer is attributable to migration of saline water through wells, an xtensive well-testing program was conducted in the Niles Cone area and vicinity (12). he results from the tests indicated that abandoned, defective and inadequately onstructed wells have allowed and are allowing saline water in the Newark aquifer o enter fresh ground water occurring in deeper producing aquifers. Abandoned ater wells often are difficult to locate and seal. Existing records show that here are some deep abandoned water wells in the Bay Plain, probably in the Niles one area, that cannot now be located in the field. Abandoned wells are frequently overed by streets, houses, or other developments. They are considered potential roblem wells because of the inevitable corrosion of well casings.

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* Asterisks indicate sources used in compiltation of Areal Geology, Plate 7.

APPENDIX D

APPLICATIONS TO APPROPRIATE WATER IN

ALAMEDA COUNTY AREA

Filed with the State Water Rights Board
under provisions of Water Code,
State of California
as of December 28, 1961

APPLICATIONS TO APPROPRIATE WATER IN ALAMEDA COUNTY AREA
FILED WITH THE STATE WATER RIGHTS BOARD
UNDER PROVISIONS OF WATER CODE, STATE OF CALIFORNIA
AS OF DECEMBER 28, 1961

Application number	Date filed	Name of applicant	Source of water supply	Location of diversion point, referenced to Mt. Diablo base and meridian					Diversion, in second-feet	Storage in acre-feet	Period of diversion	Purpose	Status
				1/4	1/4	Section	Township	Range					
3248	2/2/23	Estate of Lotta C. Crate, W. A. and Lydia B. Millet, M. R. Clifford, Ralph H. and Letitia B. Anderson, Leland H. and Bernice A. Lester Joint owners	San Lorenzo Creek	--	SW	10	3S	2W	0.15		April 1 to Sept. 30	Irrigation	License 538
3916	3/24/24	Capwell Corporation	Tassajara Creek	SW	SW	28	2S	1E	2,200 gpd		April 1 to May 15	Irrigation and domestic	License 1787
5001	4/20/26	County of Alameda	Arroyo del Valle	NW	NE	4	4S	2E	0.13			Irrigation and domestic	License 1983
5811	1/28/28	Crow Canyon Park, Inc.	Crow Canyon Creek	SE	NW	25	2S	2W	5,000 gpd		January 1 to Dec. 31	Domestic and recreation	License 1441
6103	10/24/28	S. A. and A. M. Dotters	Palomares Creek	NE NW	SE SW	12	3S	2W	0.15		May 1 to November 1 (Domestic is year-round)	Domestic and irrigation	License 1900
6173	1/29/29	Same as 3248 above	San Lorenzo Creek	--	SW	10	3S	2W	0.15		Sept. 30 to April 1	Irrigation and domestic	License 1374
7154	12/16/31	F. H. and J. R. Doossen and R. H. Weibel	(1) Laurel Spring (2) Sulphur Springs	SW SE	NW NW	8 18	5S 5S	1E 1E	0.11		January 1 to Dec. 31	Domestic	License 4256
11629	11/19/46	Coleman and Catharine Foley	Unnamed stream tributary to Alamo Creek	SW	SW	28	1S	1E		5.5	Dec. 1 to June 1	Stock water	License 4228
11683	1/6/47	A. W. Henry	Unnamed stream tributary to Arroyo de la Laguna	NW	NW	24	2S	1W		3	November 1 to June 1	Irrigation, stock water, fish culture, fire protection	License 3899
11707	1/24/47	Carmen S. Oelderman	Unnamed stream tributary to Arroyo de la Laguna	SE	SE	14	2S	1W		0.6	January 1 to Dec. 31	Stock water	License 3218
11778	3/14/47	Fred C. Wiedemann	Unnamed stream tributary to Arroyo de la Laguna	SW	SE	2	2S	1W		4	Dec. 1 to April 15	Stock water, fire protection	License 3598
11779	3/14/47	Fred C. Wiedemann	Unnamed stream tributary to Arroyo de la Laguna	NW	SE	2	2S	1W		1.3	Dec. 1 to April 15	Stock water, fire protection	License 3599
11780	3/14/47	Fred C. Wiedemann	Unnamed stream tributary to Arroyo de la Laguna	SE	SE	2	2S	1W		2.3	Dec. 1 to April 15	Stock water, fire protection	License 3600
11781	3/14/47	Fred C. Wiedemann	Unnamed stream tributary to Arroyo de la Laguna	NW	SW	2	2S	1W		2	Dec. 1 to April 15	Stock water, fire protection	License 3601
11789	3/21/47	The Roman Catholic Archbishop of San Francisco	Zeille Creek	SE	SE	22	3S	2W		30	Nov. 1 to May 1	Irrigation	License 3463
12045	8/14/47	Boy Scouts of America Oakland Area Council	Unnamed springs	NW	SE	31	4S	4E	0.05		Jan. 1 to Dec. 31	Domestic and recreation	License 5609
13279	8/5/49	Alameda County Water District	Alameda Creek (underground storage)	Various points between NE NE	NE NE	21 24	4S 4S	1W and 2W		40,000	Oct. 1 to June 1	Irrigation and domestic	Permit 8428
13565	2/6/50	Alameda County Water District	Alameda Creek (underground storage)	Same as above						40,000	Oct. 1 to June 1	Municipal	Permit 8429
15483	8/26/53	Peterson Tractor and Equipment Company	Unnamed stream tributary to Arroyo de la Laguna (JJJ Reservoir)	SW	NW	35	2S	1W		67	Oct. 1 to June 1	Irrigation and stock water	Permit 9892
16704	10/28/55	Walter S. Johnson	Arroyo de la Laguna	NE	NE	30	3S	1E	0.66		April 15 to Oct. 31	Irrigation	License 5471
17002	4/16/56	Pleasanton Township County Water District	Arroyo del Valle (Sanatorium Reservoir) 45,000 acre-feet, rest underground	SE	NW	3	4S	2E		60,000	January 1 to Dec. 31	Municipal, domestic, irrigation, industrial, recreation	Permit 11319
17003	4/16/56	Alameda County Water District	Arroyo del Valle	SE	NW	3	4S	2E		60,000	January 1 to Dec. 31	Municipal, domestic, irrigation, industrial, recreation	
17419	1/9/57	E. R., N. H., E. O., E. C., J. C., F. E., and E. M. Jensen, A. W. Oliver, and L. F. Zaharis	(1) Crow Creek (2) Crow Creek (3) Eden Creek	SW NW NW	SE NW NW	25 31 31	2S 2S 2S	2W 1W 1W		1 0.5 1	January 1 to May 1	Irrigation, stock water	License 6312
17441	1/29/57	F. T. and A. J. Davilla	Unnamed stream tributary to Hollis Creek	NE	SW	32	2S	1W		2	Oct. 1 to April 1	Stock water	License 5864
17444	1/29/57	Robert L. Beck	Collier Canyon Creek	NW	NE	25	2S	1E		3.6	Oct. 1 to May 1	Irrigation, stock water	Permit 10999
17485	2/27/57	Dyer Estate Company	Unnamed stream tributary to Arroyo Las Positas	SW	NW	19	2S	3E		3.2	Nov. 1 to May 31	Stock water	Permit 11041
17617	5/21/57	Alameda County Flood Control and Water Conservation District	(1) San Lorenzo Creek (San Lorenzo Cr. Res., 440 AF) (2) Cull Creek (Cull Cr. Res., capacity 350 AF)	SE SW	NW NW	11 2	3S 3S	2W 2W	3 3	1,100 1/ 900 1/	Jan. 1 to Dec. 31 Jan. 1 to Dec. 31	Irrigation, recreation	Permit 12176
17667	6/20/57	Michael and O. M. Huber	Arroyo Seco	SE	NE	28	3S	3E		10	Dec. 1 to May 1	Stock water	License 6383
17768	8/13/57	Alameda County Flood Control and Water Conservation District	(1) Arroyo Mocho (2) Arroyo Las Positas All underground storage	NE NW	NE NW	1 11	4S 3S	2E 1E		10,000 10,000	Jan. 1 to Dec. 31	Domestic, irrigation, municipal, industrial, recreation	Pending
18020	2/28/58	Joseph Eastwood, Jr.	Hollis Creek	NE	NE	6	3S	1W		14	Nov. 1 to June 1	Stock water	Permit 11680
18117	5/2/58	Joseph Eastwood, Jr.	Hollis Canyon	NW	SW	31	2S	1W		36	Nov. 1 to June 1	Irrigation, stock water	Permit 11681
18475	1/13/59	City and County of San Francisco	San Antonio Creek (San Antonio Reservoir, 51,000 acre-feet)	NW	SE	22	4S	1E		20,000	Jan. 1 to Dec. 31	Municipal, domestic	Permit 12648
19019	10/6/59	Carl and Haldis H. Ekoos	San Lorenzo Creek	SE	SW	10	3S	2W	5,000 gpd		Jan. 1 to Dec. 31	Irrigation	Permit 12307
19650	8/5/60	Paterson Tractor Co.	Big Canyon	SE	SE	27	2S	1W		232	Nov. 1 to April 30	Irrigation, domestic, stock water	Permit 12938

1/ An additional 1,000 acre-feet from either or both sources will be stored underground, together with excess amounts named above. Reservoirs to be filled several times each year to control flood peaks.

APPENDIX E

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951

Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches									
						March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
LIVERMORE VALLEY UNIT, 1949 AND 1950															
Beans	1	1949	(3S/1E-1P1) (3S/1E-12E1)	Loam, clay loam, and gravelly sandy loam	127			4.2	1.4	3.9	5.7	0.2			15.4
	2	1949	3S/2E-1N2	Loam poorly drained	35					1.5	3.3	1.6			6.4
	3	1950	3S/1E-12F1	Loam and gravelly sandy loam	40			2.2		1.6	5.0				8.8
						Weighted mean depths:									
							1949		13.5 inches (1.12 feet)						
							1950		8.8 inches (0.73 foot)						
							1949 and 1950		12.6 inches (1.05 feet)						
Nursery Roses	4	1949	(3S/1E-12M1) (3S/1E-12P1)	Loam, clay loam, and gravelly fine sandy loam	36.2		7.1	6.5	10.7	7.7	10.3				42.3
	4	1949	3S/1E-12P1	Loam and gravelly fine sandy loam	37		4.1	4.9	10.2	8.0	4.8				32.0
	4	1949	3S/1E-12P1	Loam and gravelly fine sandy loam	34		7.0	6.1	11.0	7.9	7.1				39.1
	5	1949	3S/2E-11K1	Clay and gravelly sandy loam	40		4.3	2.8	5.7	5.7	5.3	3.0	8.5		35.3
	5	1950	3S/2E-11K1	Clay and gravelly sandy loam	45	2.1	2.8	4.3	4.9	5.9	5.3	4.9	2.7		32.9
						Weighted mean depths:									
							1949		37.1 inches (3.09 feet)						
							1950		32.9 inches (2.74 feet)						
							1949 and 1950		36.1 inches (3.01 feet)						
Orchard Walnuts	6	1949	3S/2E-20M1	Loam	16			6.9	5.0	4.9	7.9				24.7
	6	1950	3S/2E-20M1	Loam	16			2.0	9.9	12.9	2.6				27.4
						Weighted mean depths:									
							1949		24.7 inches (2.06 feet)						
							1950		27.4 inches (2.28 feet)						
							1949 and 1950		26.0 inches (2.17 feet)						
Walnuts, young	7	1949	3S/2E-17J1	Loam	64		0.5	2.4	3.2	2.2	1.3	2.8			12.4
						Weighted mean depth:									
									12.4 inches (1.03 feet)						

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951
(continued)

Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches: March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Pasture	8	1949	3S/1E-18K1	Clay adobe and loam	75.6		5.4	14.4	13.2	16.1	17.0	11.7	10.5		88.3
	9	1949	3S/1E-18Q1	Fine sandy loam	100			0.4	11.0	17.0	4.7	7.0	2.5		42.6
	10	1949	3S/2E-17C1	Gravelly sandy loam	10		27.9	34.1	38.2	29.6	25.2	16.1			171.1
	11	1949	3S/2E-29D1	Loam and gravelly fine sandy loam	15		3.0	3.3	5.4	6.4	6.1	6.5	3.5	0.7	34.9
	8	1950	3S/1E-18K1	Clay adobe and loam	84			8.8	14.8	15.9	16.1	10.8	11.2		77.6
	9	1950	3S/1E-18Q1	Fine sandy loam	100			7.8	1.5	8.5	7.6	4.7	7.2		37.3
	11	1950	3S/2E-29D1	Loam and gravelly fine sandy loam	15		1.9	5.8	6.7	7.9	7.5	7.8	6.9		44.5
						Weighted mean depths:									
						1949				65.6 inches (5.46 feet)					
						1950				54.9 inches (4.57 feet)					
						1949 and 1950				60.3 inches (5.02 feet)					
Sugar beets	12	1949	3S/1E-16F1	Loam and silty clay loam	20			1.0	0.8	7.1	5.2				14.1
	13	1950	3S/1E-2P1	Clay adobe and silty clay loam	35				13.5	15.2	8.6				37.3
	14	1950	3S/1E-8H1	Clay adobe	10.5				24.8	7.9	4.1				36.8
						Weighted mean depths:									
						1949				14.1 inches (1.18 feet)					
						1950				37.2 inches (3.10 feet)					
						1949 and 1950				30.2 inches (2.51 feet)					
Tomatoes	15	1949	3S/1E-2N1	Clay adobe	12				8.1	7.1	1.7				16.9
	13	1949	3S/1E-2P1	Clay adobe and silty clay loam	50.4				4.2	3.2	3.4	2.4			13.2
	16	1949	3S/1E-11H2	Clay loam and gravelly sandy loam	58			1.0	4.5	6.5	6.2	0.7			18.9
	17	1949	(3S/1E-11J1) (3S/1E-11Q1)	Clay, sandy, and gravelly loam	82				6.5	7.0	7.6				21.1
	1	1950	3S/1E-1P1	Loam, clay loam, and gravelly sandy loam	65					9.5	5.1				14.6
	13	1950	3S/1E-2P1	Clay adobe and silty clay loam	45			1.3	4.1	4.9	4.6	1.6			16.5
						Weighted mean depths:									
						1949				18.3 inches (1.53 feet)					
						1950				15.4 inches (1.28 feet)					
						1949 and 1950				17.3 inches (1.44 feet)					

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951
(continued)

Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches: March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Truck															
Cucumbers	15	1949	3S/1E-2N1	Clay adobe	15.4				11.3	8.0	3.8				23.1
	1	1949	3S/1E-12E1	Loam and gravelly sandy loam	17.5		0.7	3.0							3.7
	14	1950	3S/1E-8H1	Clay adobe	20			3.9	10.3	12.8	11.1				38.1
						Weighted mean depths:									
						1949			12.8 inches (1.07 feet)						
						1950			38.1 inches (3.17 feet)						
						1949 and 1950			22.4 inches (1.86 feet)						
Vineyard	18	1949	3S/2E-15K1	Gravelly sandy loam	60.5		0.6	4.2	2.8	2.6	2.5				12.7
						Weighted mean depth:									
						1949			12.7 inches (1.06 feet)						
SOUTHERN ALAMEDA UNIT, 1950 AND 1951															
Beans	19	1950	4S/1W-29N1	Clay loams	55				3.8	5.8	2.6	0.1			12.3
	19	1951	4S/1W-29N1	Clay loams	55				2.1	13.3	6.4				21.8
						Weighted mean depths:									
						1950			12.3 inches (1.02 feet)						
						1951			21.8 inches (1.82 feet)						
						1950 and 1951			17.0 inches (1.41 feet)						
Orchard															
Apricots	20	1950	4S/1W-26Q1	Loams and clay loams	18			4.8	2.0	0.1	5.9	0.3			13.1
	21	1950	4S/1W-33C1	Clay loams	4			9.3				14.5			23.8
	22	1950	4S/1W-34R2	Loam and clay loam	45		0.4	3.5	1.5						5.4
	23	1951	4S/1W-17E2	Clay loams	20			5.5	1.7		2.1				9.3
	20	1951	4S/1W-26Q1	Loams and clay loams	18			0.5	5.7	0.2	6.4	0.4			13.2
	21	1951	4S/1W-33C1	Clay loams	4			8.5				10.2			18.7
						Weighted mean depths:									
						1950			8.6 inches (0.72 foot)						
						1951			11.9 inches (0.99 foot)						
						1950 and 1951			9.8 inches (0.82 foot)						

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951
(continued)

Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Orchard (continued)															
Cherries	24	1950	4S/1W-29B1	Clay loams	4		6.0	4.6	5.2						15.8
	21	1950	4S/1W-33C1	Clay loams	5			8.4			12.0				20.4
	21	1951	4S/1W-33C1	Clay loams	9			7.2				9.7			16.9
						Weighted mean depths:									
							1950		18.3 inches (1.52 feet)						
							1951		16.9 inches (1.41 feet)						
							1950 and 1951		17.6 inches (1.47 feet)						
Walnuts	25	1950	5S/1W-3F1	Clay loams	26			2.4	5.1	3.4	2.1				13.0
	26	1950	5S/1W-24H1	Loams	13				5.2	5.9	4.5				15.6
						Weighted mean depth:									
							1950		13.9 inches (1.16 feet)						
TOTAL ORCHARD						Weighted mean depths:									
							1950		10.6 inches (0.88 foot)						
							1951		12.7 inches (1.06 feet)						
							1950 and 1951		11.3 inches (0.94 foot)						
Pasture	27	1950	3S/3W-24H1	Adobe soils	31		2.5	7.4	6.1	6.4	5.8	5.2	3.6		37.0
	28	1950	(4S/1W-7L1) (4S/1W-7R2)	Adobe soils	215.5		1.6	5.7	7.3	7.6	7.9	5.8	4.3		40.2
	28	1951	(4S/1W-7L1) (4S/1W-7R2)	Adobe soils	215.5		2.4	6.8	9.5	7.2	7.3	1.3			34.5
						Weighted mean depths:									
							1950		39.8 inches (3.32 feet)						
							1951		34.5 inches (2.87 feet)						
							1950 and 1951		37.3 inches (3.11 feet)						
Sugar beets	29	1950	4S/1W-28P3	Clay loams	12			9.9	4.7	0.6					15.2
	19	1950	4S/1W-29N1	Clay loams	55			1.0	8.9	6.1	1.5				17.5
	29	1951	4S/1W-28P3	Clay loams	11				17.5	8.5	3.4				29.4
	19	1951	4S/1W-29N1	Clay loams	55			2.2	9.4	7.3	3.5				22.4
	30	1951	4S/2W-27K1	Adobe soils	57		1.5	0.7	3.7	3.0	0.9				9.8
						Weighted mean depths:									
							1950		17.1 inches (1.42 feet)						
							1951		17.2 inches (1.43 feet)						
							1950 and 1951		17.2 inches (1.43 feet)						

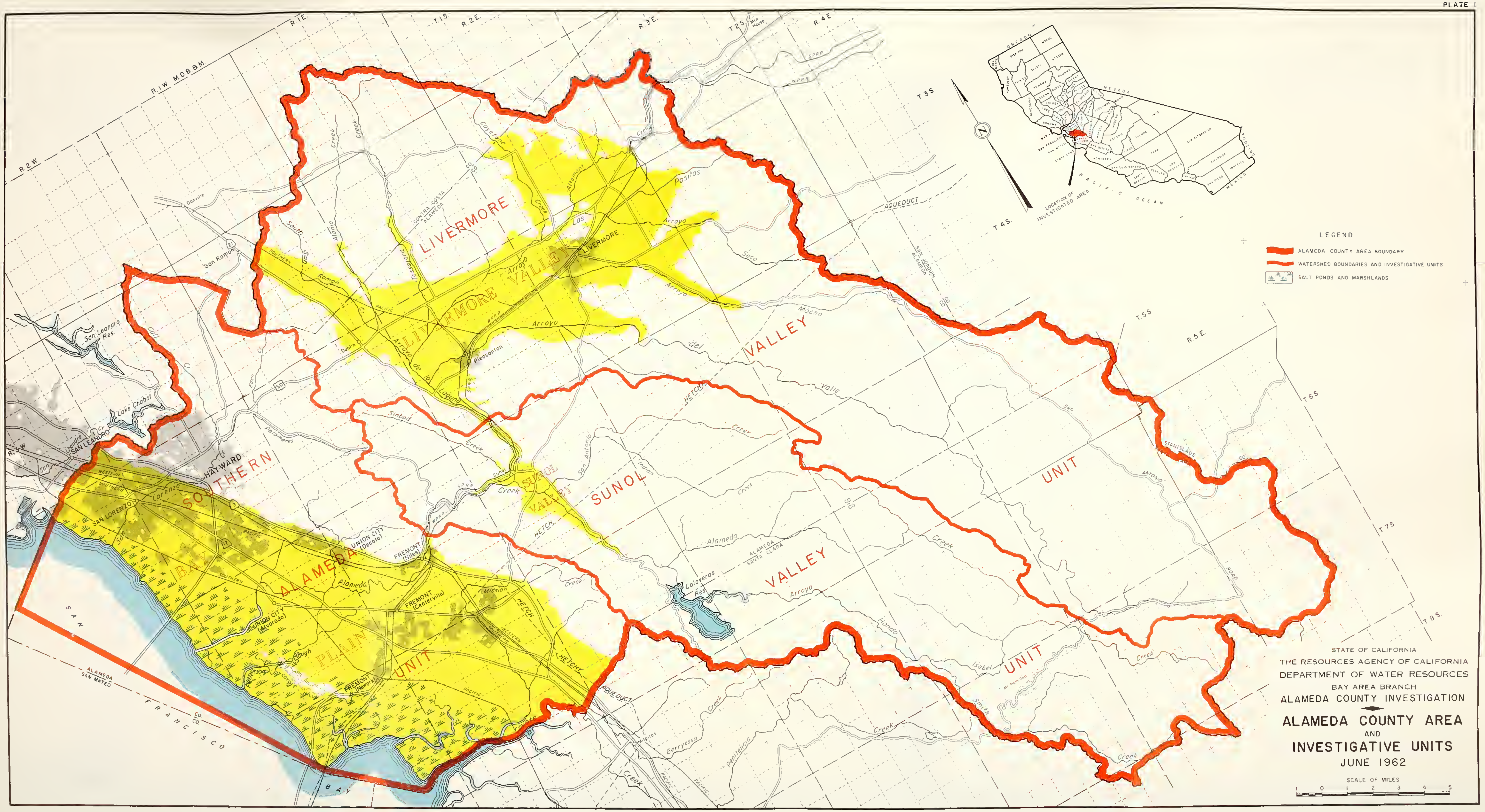
APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951
(continued)

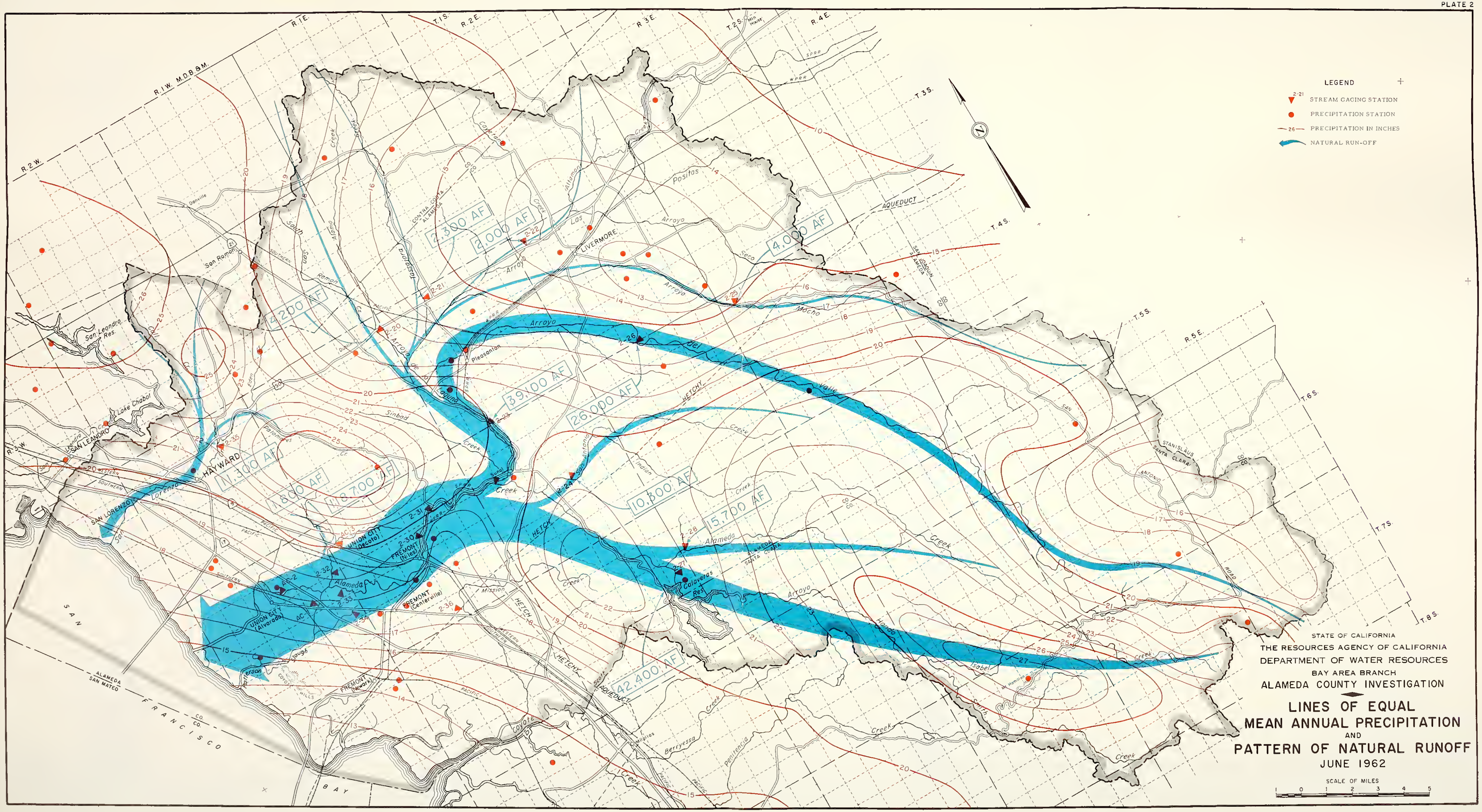
Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches: March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Tomatoes	31	1950	4S/2W-24J1	Clay loams	20			5.4		4.0	3.7				13.1
	30	1950	4S/2W-27K1	Adobe soils	40				4.3	1.5	2.1	0.7	0.9		9.5
	30	1951	4S/2W-27K1	Adobe soils	25			0.9	5.7	0.9	4.3	3.4			15.2
						Weighted mean depths:									
							1950		10.7 inches (0.89 foot)						
							1951		15.2 inches (1.27 feet)						
							1950 and 1951		12.1 inches (1.01 feet)						
Truck															
Corn	32	1951	4S/1W-34J1	Loams and clay loams	8				6.8	4.4					11.2
						Weighted mean depth:			11.2 inches (0.93 foot)						
Cucumbers	29	1950	4S/1W-28P3	Clay loams	8			3.0	7.6	5.6	6.3	0.9			23.4
	33	1951	4S/1W-18K1	Loams	22				2.2	2.6	3.7				8.5
	29	1951	4S/1W-28P3	Clay loams	9		8.5		6.2	10.2	4.8				29.7
	32	1951	4S/1W-34J1	Loams and clay loams	4			0.9	4.0	5.0	6.6	0.9			17.4
						Weighted mean depths:									
							1950		23.4 inches (1.95 feet)						
							1951		15.0 inches (1.25 feet)						
							1950 and 1951		16.5 inches (1.38 feet)						
Lettuce	34	1950	4S/2W-14F3	Loams	110		1.3	3.0	3.1	3.6	2.7	2.9	1.0		17.6
	35	1951	4S/2W-22K1	Loams	5				7.2	3.0	6.2	0.9			17.3
						Weighted mean depths:									
							1950		17.6 inches (1.46 feet)						
							1951		17.3 inches (1.44 feet)						
							1950 and 1951		17.6 inches (1.46 feet)						
Onions	35	1951	4S/2W-22K1	Loams	3		3.0	5.1	2.0	3.2					13.3
						Weighted mean depth:									
							1951		13.3 inches (1.11 feet)						

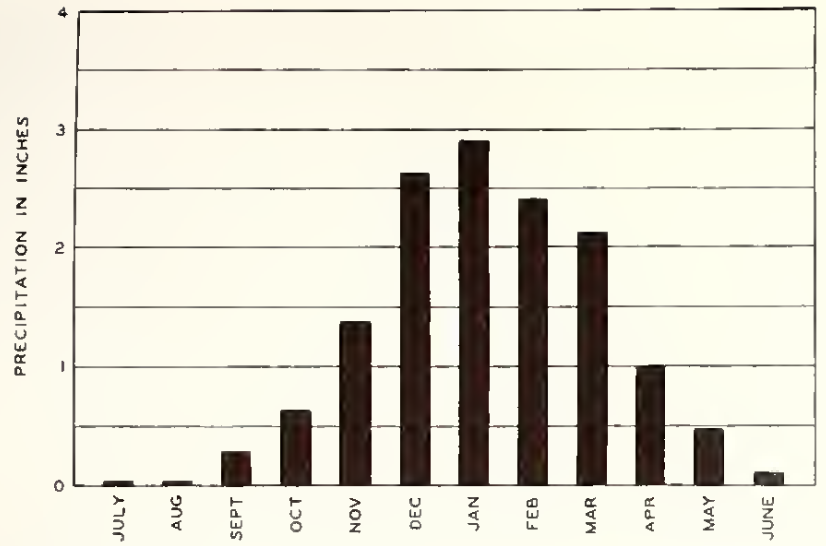
APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN
ALAMEDA COUNTY AREA IN 1949, 1950, AND 1951
(continued)

Crop	Number on Plate 13	Season	Well number	Soil type	Acres irrigated	Depth of application, in inches									
						March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Truck (continued)															
Potatoes	35	1950	4S/2W-22K1	Loams	75			0.4	2.8	3.0	3.6	1.5			11.3
	35	1951	4S/2W-22K1	Loams	75				4.4	5.3	4.4	1.1			15.2
						Weighted mean depths:									
						1950			11.3 inches (0.94 foot)						
						1951			15.2 inches (1.27 feet)						
						1950 and 1951			13.3 inches (1.11 feet)						
Strawberries	22	1950	4S/1W-34R2	Loam and clay loam	3			6.6	4.1	10.3	6.0				27.0
						Weighted mean depth: 1950 27.0 inches (2.25 feet)									
General truck	36	1950	4S/2W-2P1	Loams and clay loams	92			4.3	6.3	5.2	4.6	1.4			21.8
(Includes	37	1950	4S/2W-2Q1	Loams and clay loams	142			1.0	4.8	2.8	2.9	0.2			11.7
beans, cabbage,	38	1950	4S/2W-23K1	Loams and clay loams	125		1.0	3.4	4.5	3.6	2.5	2.6	1.0		18.6
cauliflower, corn,	36	1951	4S/2W-2P1	Loams and clay loams	95			1.0	1.9	4.2	2.3				9.4
cucumbers, lettuce,	37	1951	4S/2W-2Q1	Loams and clay loams	140		0.7	2.5	2.4	3.1	2.0				10.7
sugar beets, and	39	1951	4S/2W-10N1	Loams and clay Loams	60				5.9	2.5	2.3				10.7
tomatoes)	40	1951	4S/2W-15G2	Loams	75		2.4	0.7	3.3	4.1	4.5	2.0			17.0
						Weighted mean depths:									
						1950			16.7 inches (1.39 feet)						
						1951			11.6 inches (0.97 foot)						
						1950 and 1951			14.1 inches (1.18 feet)						
TOTAL TRUCK						Weighted mean depths:									
						1950			16.3 inches (1.36 feet)						
						1951			12.5 inches (1.04 feet)						
						1950 and 1951			14.5 inches (1.21 feet)						

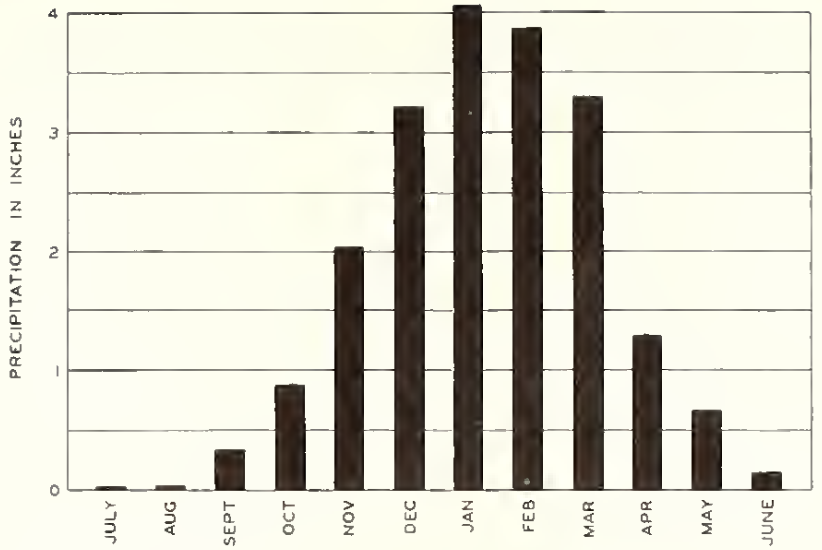
PLATE 1


LEGEND
ALAMEDA COUNTY AREA BOUNDARY
WATERSHED BOUNDARIES AND INVESTIGATIVE UNITS
SALT PONDS AND MARSHLANDS
LOCATION OF INVESTIGATED AREA
LIVERMORE VALLEY
SUNOL VALLEY UNIT
SOUTHERN ALAMEDA BAY PLAIN UNIT
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
ALAMEDA COUNTY AREA
AND
INVESTIGATIVE UNITS
JUNE 1962
SCALE OF MILES

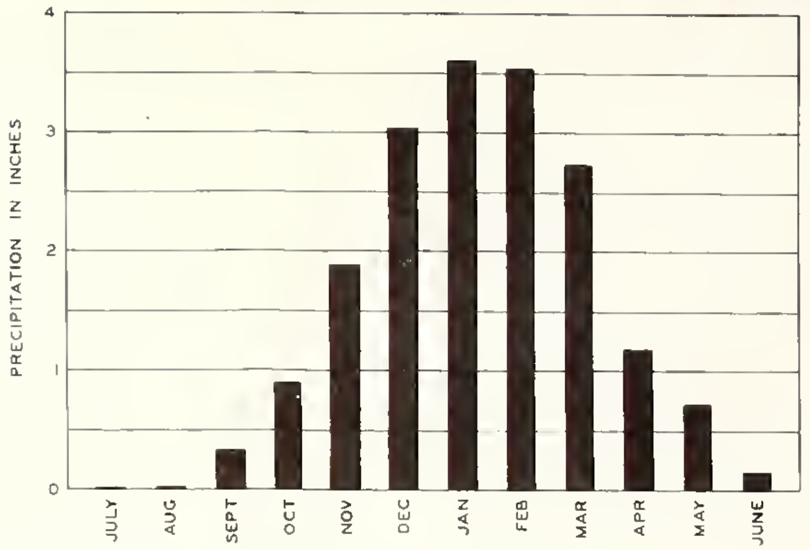

LEGEND
2-21 STREAM GAGING STATION
PRECIPITATION STATION
26 PRECIPITATION IN INCHES
NATURAL RUN-OFF
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
LINES OF EQUAL
MEAN ANNUAL PRECIPITATION
AND
PATTERN OF NATURAL RUNOFF
JUNE 1962
SCALE OF MILES
1 0 1 2 3 4 5
2,300 AF
2,000 AF
4,000 AF
4,200 AF
39,100 AF
26,000 AF
11,300 AF
1,800 AF
8,700 AF
10,300 AF
15,700 AF
42,400 AF
LIVERMORE
Pleasanton
HAYWARD
SAN LEANDRO
San Leandro Res.
Lake Chabot
UNION CITY (Decoto)
UNION CITY (Alvarado)
FREMONT (Niles)
FREMONT (Centerville)
FREMONT (Newark)
Calaveras Res.
SAN FRANCISCO BAY
ALAMEDA
SAN MATEO
AQUEDUCT
HETCH HETCHY



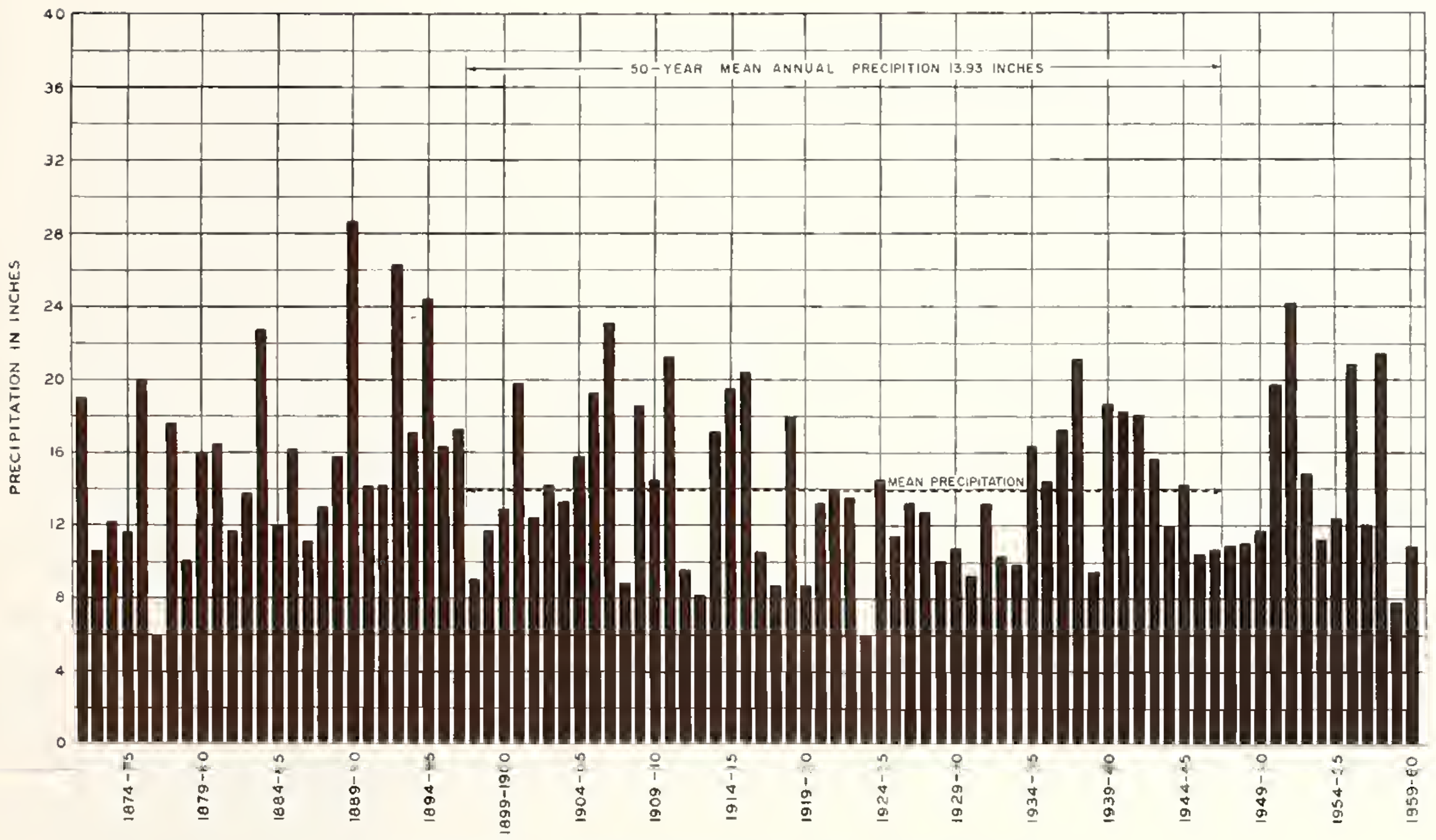
MEAN MONTHLY PRECIPITATION AT LIVERMORE



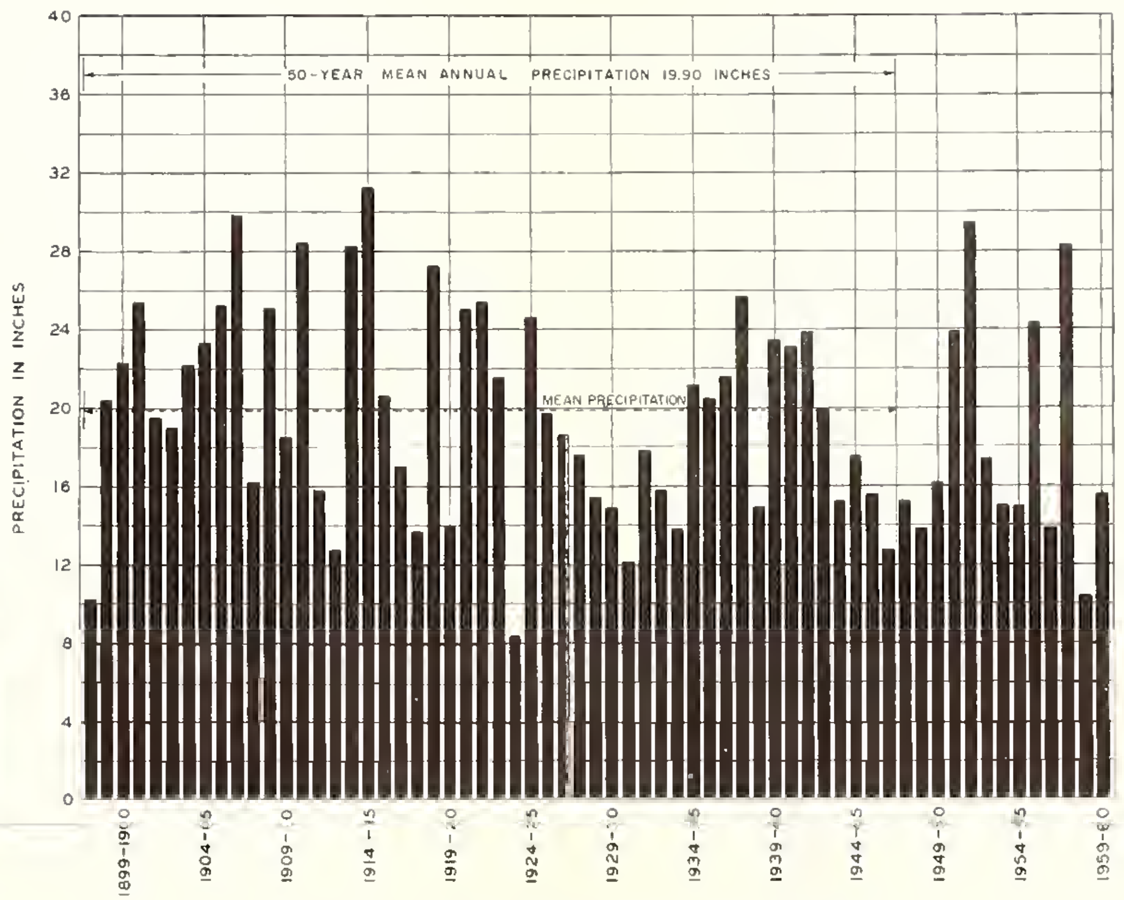
MEAN MONTHLY PRECIPITATION AT SUNOL



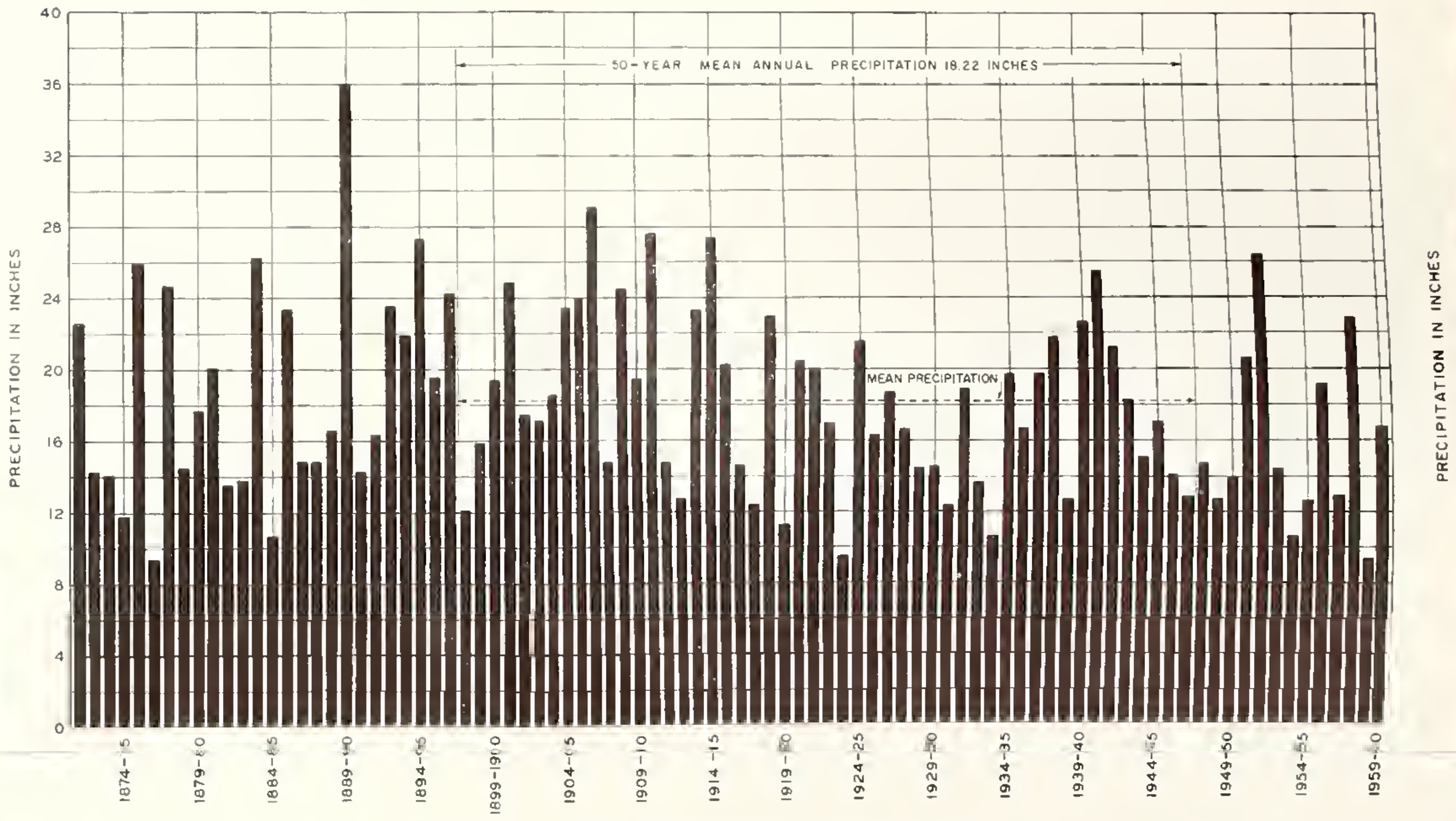
MEAN MONTHLY PRECIPITATION NEAR NILES



ANNUAL PRECIPITATION AT LIVERMORE

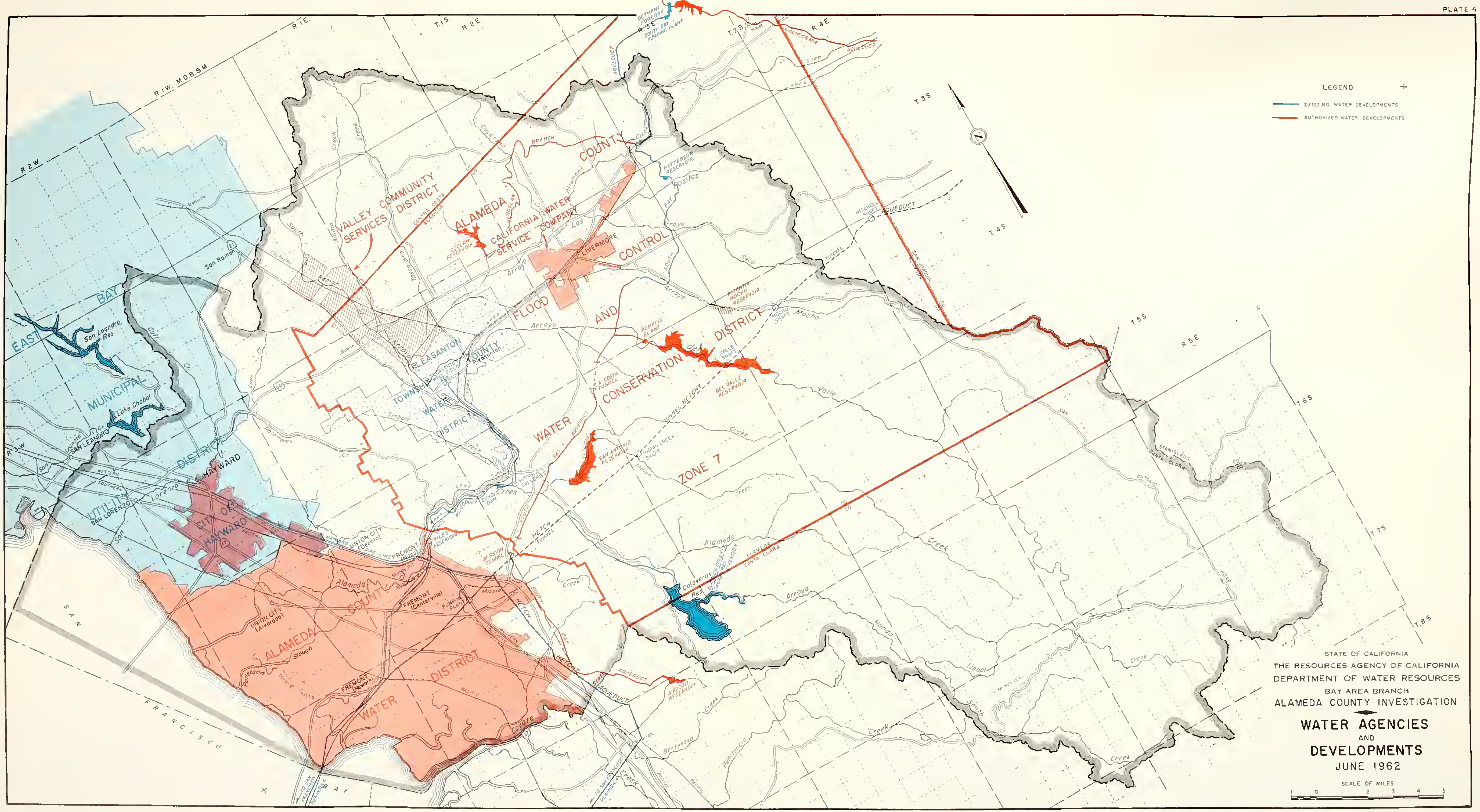


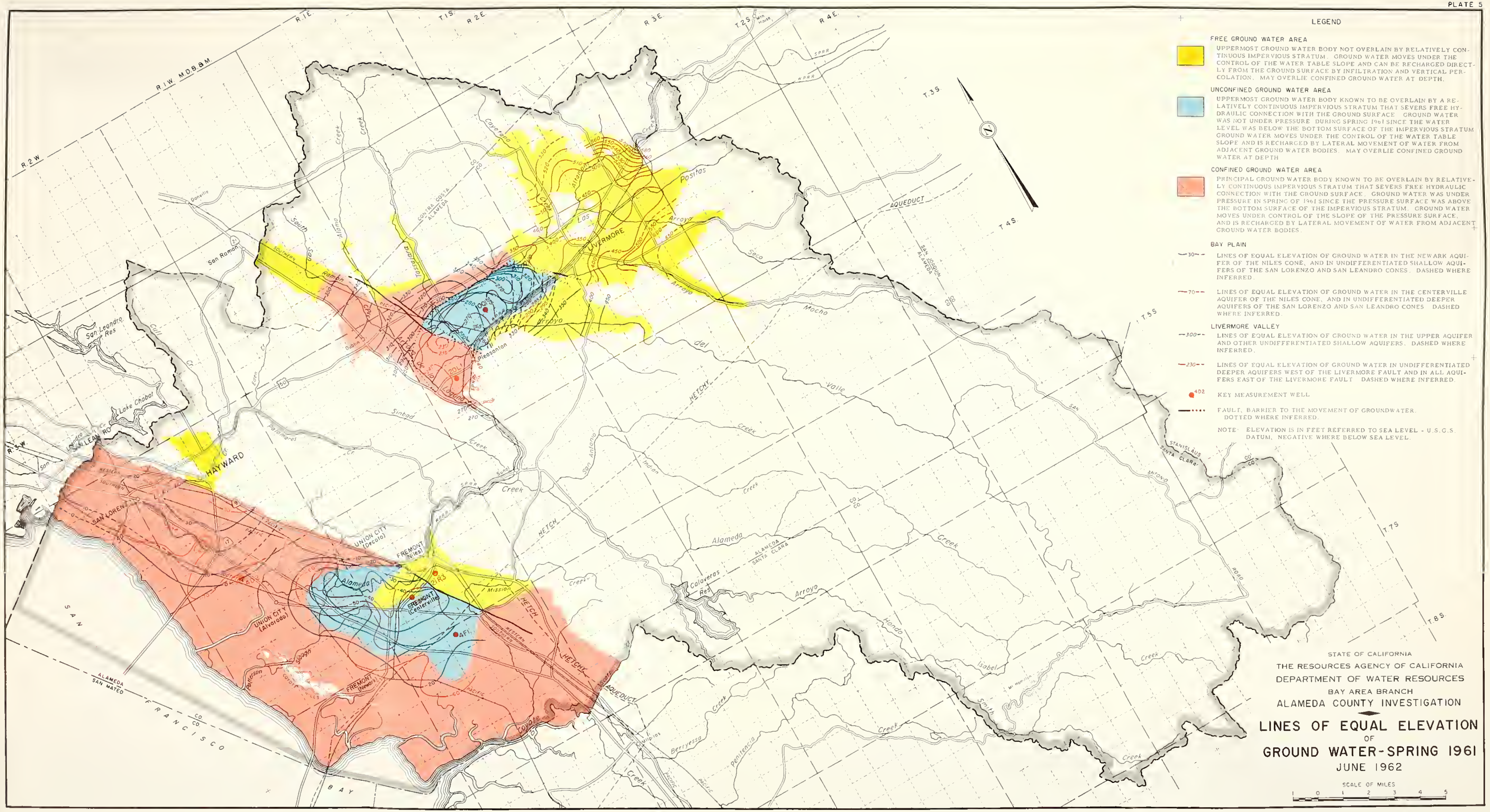
ANNUAL PRECIPITATION AT SUNOL

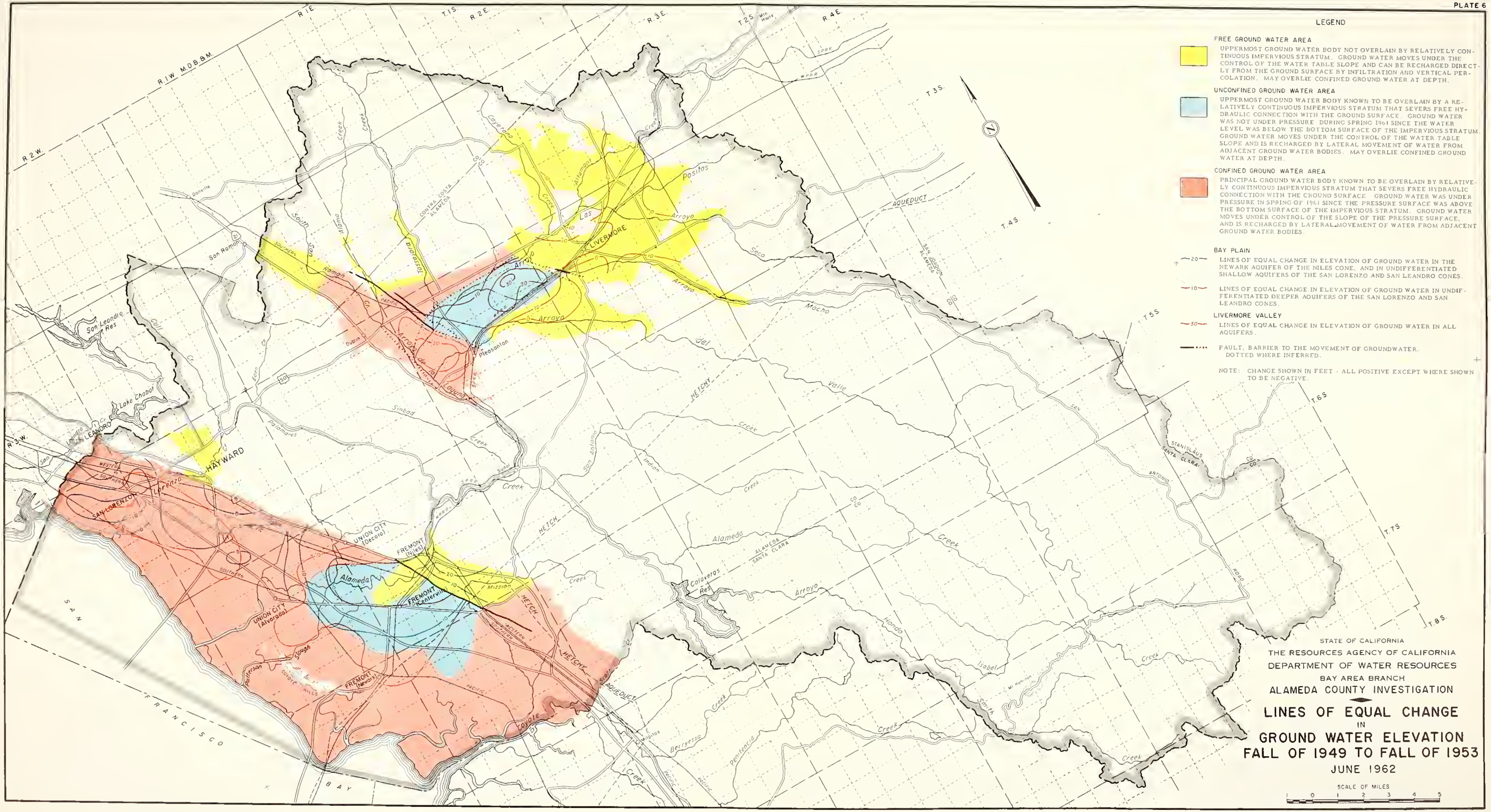


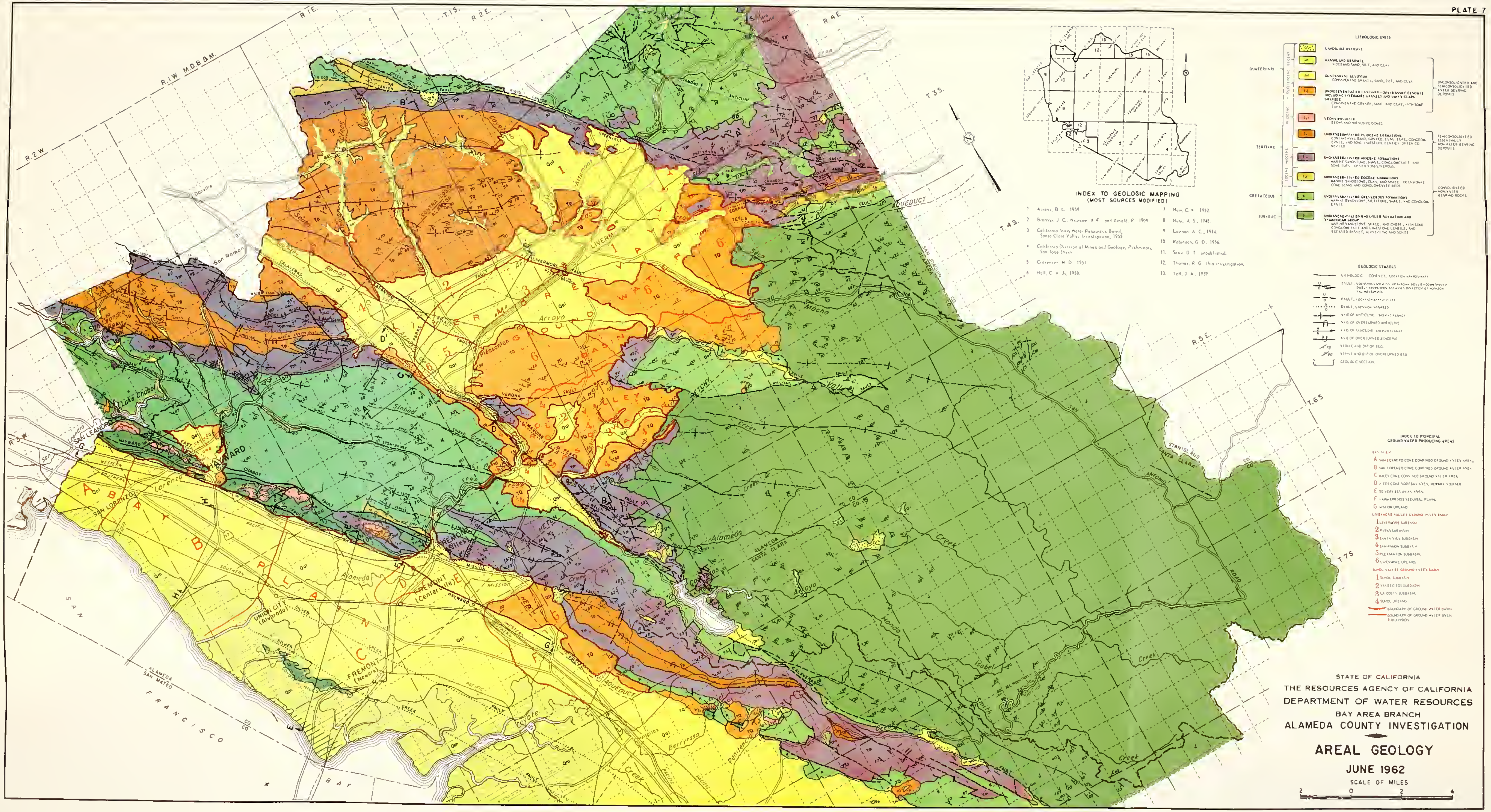
ANNUAL PRECIPITATION NEAR NILES

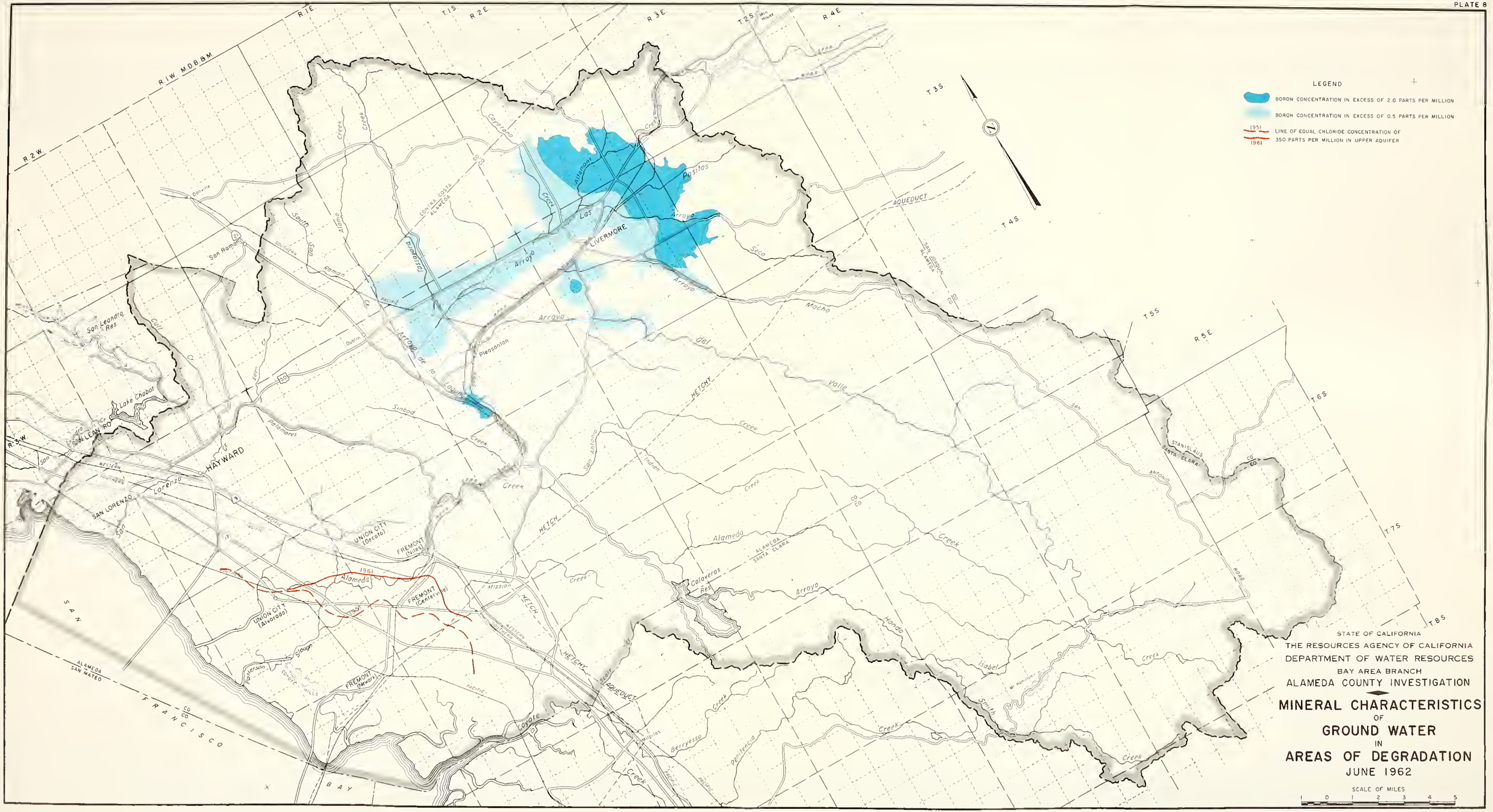
MEAN MONTHLY AND ANNUAL PRECIPITATION AT LIVERMORE, AT SUNOL, AND NEAR NILES
BASED ON THE 50 YEAR PERIOD 1897-98 TO 1946-47


LEGEND
EXISTING WATER DEVELOPMENTS
AUTHORIZED WATER DEVELOPMENTS
EAST BAY MUNICIPAL UTILITY DISTRICT
VALLEY COMMUNITY SERVICES DISTRICT
CALIFORNIA WATER SERVICE COMPANY
ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
ZONE 7
PLEASANTON TOWNSHIP COUNTY WATER DISTRICT
CITY OF HAYWARD
ALAMEDA COUNTY WATER DISTRICT
LIVERMORE
PLEASANTON
HAYWARD
SAN LEANDRO
SAN LORENZO
UNION CITY (Decoto)
UNION CITY (Alvarado)
FREMONT (Niles)
FREMONT (Centerville)
FREMONT (Newark)
San Leandro Res.
Lake Chabot
Calaveras Res.
DEL VALLE RESERVOIR
SAN ANTONIO RESERVOIR
PATTERSON RESERVOIR
SOUTH BAY PUMPING PLANT
BETHANY FOREBAY
SOUTH BAY AQUEDUCT
HETCH HETCHY TUNNEL
MISSION TUNNEL
SAN FRANCISCO BAY
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
WATER AGENCIES
AND
DEVELOPMENTS
JUNE 1962
SCALE OF MILES
1 0 1 2 3 4 5


LEGEND
FREE GROUND WATER AREA
UPPERMOST GROUND WATER BODY NOT OVERLAIN BY RELATIVELY CONTINUOUS IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER THE CONTROL OF THE WATER TABLE SLOPE AND CAN BE RECHARGED DIRECTLY FROM THE GROUND SURFACE BY INFILTRATION AND VERTICAL PERCOLATION. MAY OVERLIE CONFINED GROUND WATER AT DEPTH.
UNCONFINED GROUND WATER AREA
UPPERMOST GROUND WATER BODY KNOWN TO BE OVERLAIN BY A RELATIVELY CONTINUOUS IMPERVIOUS STRATUM THAT SEVERS FREE HYDRAULIC CONNECTION WITH THE GROUND SURFACE. GROUND WATER WAS NOT UNDER PRESSURE DURING SPRING 1961 SINCE THE WATER LEVEL WAS BELOW THE BOTTOM SURFACE OF THE IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER THE CONTROL OF THE WATER TABLE SLOPE AND IS RECHARGED BY LATERAL MOVEMENT OF WATER FROM ADJACENT GROUND WATER BODIES. MAY OVERLIE CONFINED GROUND WATER AT DEPTH
CONFINED GROUND WATER AREA
PRINCIPAL GROUND WATER BODY KNOWN TO BE OVERLAIN BY RELATIVELY CONTINUOUS IMPERVIOUS STRATUM THAT SEVERS FREE HYDRAULIC CONNECTION WITH THE GROUND SURFACE. GROUND WATER WAS UNDER PRESSURE IN SPRING OF 1961 SINCE THE PRESSURE SURFACE WAS ABOVE THE BOTTOM SURFACE OF THE IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER CONTROL OF THE SLOPE OF THE PRESSURE SURFACE, AND IS RECHARGED BY LATERAL MOVEMENT OF WATER FROM ADJACENT GROUND WATER BODIES.
BAY PLAIN
30
LINES OF EQUAL ELEVATION OF GROUND WATER IN THE NEWARK AQUIFER OF THE NILES CONE, AND IN UNDIFFERENTIATED SHALLOW AQUIFERS OF THE SAN LORENZO AND SAN LEANDRO CONES. DASHED WHERE INFERRED.
70
LINES OF EQUAL ELEVATION OF GROUND WATER IN THE CENTERVILLE AQUIFER OF THE NILES CONE, AND IN UNDIFFERENTIATED DEEPER AQUIFERS OF THE SAN LORENZO AND SAN LEANDRO CONES. DASHED WHERE INFERRED.
LIVERMORE VALLEY
300
LINES OF EQUAL ELEVATION OF GROUND WATER IN THE UPPER AQUIFER AND OTHER UNDIFFERENTIATED SHALLOW AQUIFERS. DASHED WHERE INFERRED.
230
LINES OF EQUAL ELEVATION OF GROUND WATER IN UNDIFFERENTIATED DEEPER AQUIFERS WEST OF THE LIVERMORE FAULT AND IN ALL AQUIFERS EAST OF THE LIVERMORE FAULT. DASHED WHERE INFERRED.
4D2
KEY MEASUREMENT WELL
FAULT, BARRIER TO THE MOVEMENT OF GROUNDWATER. DOTTED WHERE INFERRED.
NOTE: ELEVATION IS IN FEET REFERRED TO SEA LEVEL - U.S.G.S. DATUM, NEGATIVE WHERE BELOW SEA LEVEL.
R.1 E.
R.2 E.
R.3 E.
R.4 E.
R.2 W.
R.3 W.
R.1 W. M.D.B.&M.
T.1 S.
T.2 S.
T.3 S.
T.4 S.
T.5 S.
T.7 S.
T.8 S.
N
HAYWARD
LIVERMORE
Pleasanton
Dublin
San Ramon
San Leandro Res
Lake Chabot
SAN LORENZO
UNION CITY (Decoto)
UNION CITY (Alvarado)
FREMONT (Niles)
FREMONT (Centerville)
FREMONT (Newark)
AQUEDUCT
HETCH HETCHY
Calaveras Res
Arroyo
Positas
Las Positas
Mocho
del Valle
Alameda Creek
Sinbad
Sunol
CONTRA COSTA
ALAMEDA
SAN JOAQUIN
ALAMEDA
STANISLAUS
SANTA CLARA
ALAMEDA
SANTA CLARA
ALAMEDA
SAN MATEO
SAN FRANCISCO BAY
Coyote
Berryessa
Penitencia
Milpitas
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
LINES OF EQUAL ELEVATION OF GROUND WATER-SPRING 1961
JUNE 1962
SCALE OF MILES
1 0 1 2 3 4 5


LEGEND
FREE GROUND WATER AREA
UPPERMOST GROUND WATER BODY NOT OVERLAIN BY RELATIVELY CONTINUOUS IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER THE CONTROL OF THE WATER TABLE SLOPE AND CAN BE RECHARGED DIRECTLY FROM THE GROUND SURFACE BY INFILTRATION AND VERTICAL PERCOLATION. MAY OVERLIE CONFINED GROUND WATER AT DEPTH.
UNCONFINED GROUND WATER AREA
UPPERMOST GROUND WATER BODY KNOWN TO BE OVERLAIN BY A RELATIVELY CONTINUOUS IMPERVIOUS STRATUM THAT SEVERS FREE HYDRAULIC CONNECTION WITH THE GROUND SURFACE. GROUND WATER WAS NOT UNDER PRESSURE DURING SPRING 1961 SINCE THE WATER LEVEL WAS BELOW THE BOTTOM SURFACE OF THE IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER THE CONTROL OF THE WATER TABLE SLOPE AND IS RECHARGED BY LATERAL MOVEMENT OF WATER FROM ADJACENT GROUND WATER BODIES. MAY OVERLIE CONFINED GROUND WATER AT DEPTH.
CONFINED GROUND WATER AREA
PRINCIPAL GROUND WATER BODY KNOWN TO BE OVERLAIN BY RELATIVELY CONTINUOUS IMPERVIOUS STRATUM THAT SEVERS FREE HYDRAULIC CONNECTION WITH THE GROUND SURFACE. GROUND WATER WAS UNDER PRESSURE IN SPRING OF 1961 SINCE THE PRESSURE SURFACE WAS ABOVE THE BOTTOM SURFACE OF THE IMPERVIOUS STRATUM. GROUND WATER MOVES UNDER CONTROL OF THE SLOPE OF THE PRESSURE SURFACE, AND IS RECHARGED BY LATERAL MOVEMENT OF WATER FROM ADJACENT GROUND WATER BODIES.
BAY PLAIN
20
LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER IN THE NEWARK AQUIFER OF THE NILES CONE, AND IN UNDIFFERENTIATED SHALLOW AQUIFERS OF THE SAN LORENZO AND SAN LEANDRO CONES.
10
LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER IN UNDIFFERENTIATED DEEPER AQUIFERS OF THE SAN LORENZO AND SAN LEANDRO CONES.
LIVERMORE VALLEY
50
LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER IN ALL AQUIFERS.
FAULT, BARRIER TO THE MOVEMENT OF GROUNDWATER. DOTTED WHERE INFERRED.
NOTE: CHANGE SHOWN IN FEET - ALL POSITIVE EXCEPT WHERE SHOWN TO BE NEGATIVE.
LIVERMORE
HAYWARD
SAN LEANDRO
SAN LORENZO
Pleasanton
Dublin
San Ramon
Danville
UNION CITY (Decoto)
UNION CITY (Alvarado)
FREMONT (Niles)
FREMONT (Centerville)
FREMONT (Newark)
Calaveras Res
San Leandro Res
Lake Chabot
SAN FRANCISCO BAY
AQUEDUCT
HETCH HETCHY
R.1 W. M.D.B.&M.
R.1 E.
R.2 E.
R.3 E.
R.4 E.
R.2 W.
R.3 W.
T.1 S.
T.2 S.
T.3 S.
T.4 S.
T.5 S.
T.6 S.
T.7 S.
T.8 S.
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
LINES OF EQUAL CHANGE
IN
GROUND WATER ELEVATION
FALL OF 1949 TO FALL OF 1953
JUNE 1962
SCALE OF MILES
1 0 1 2 3 4 5

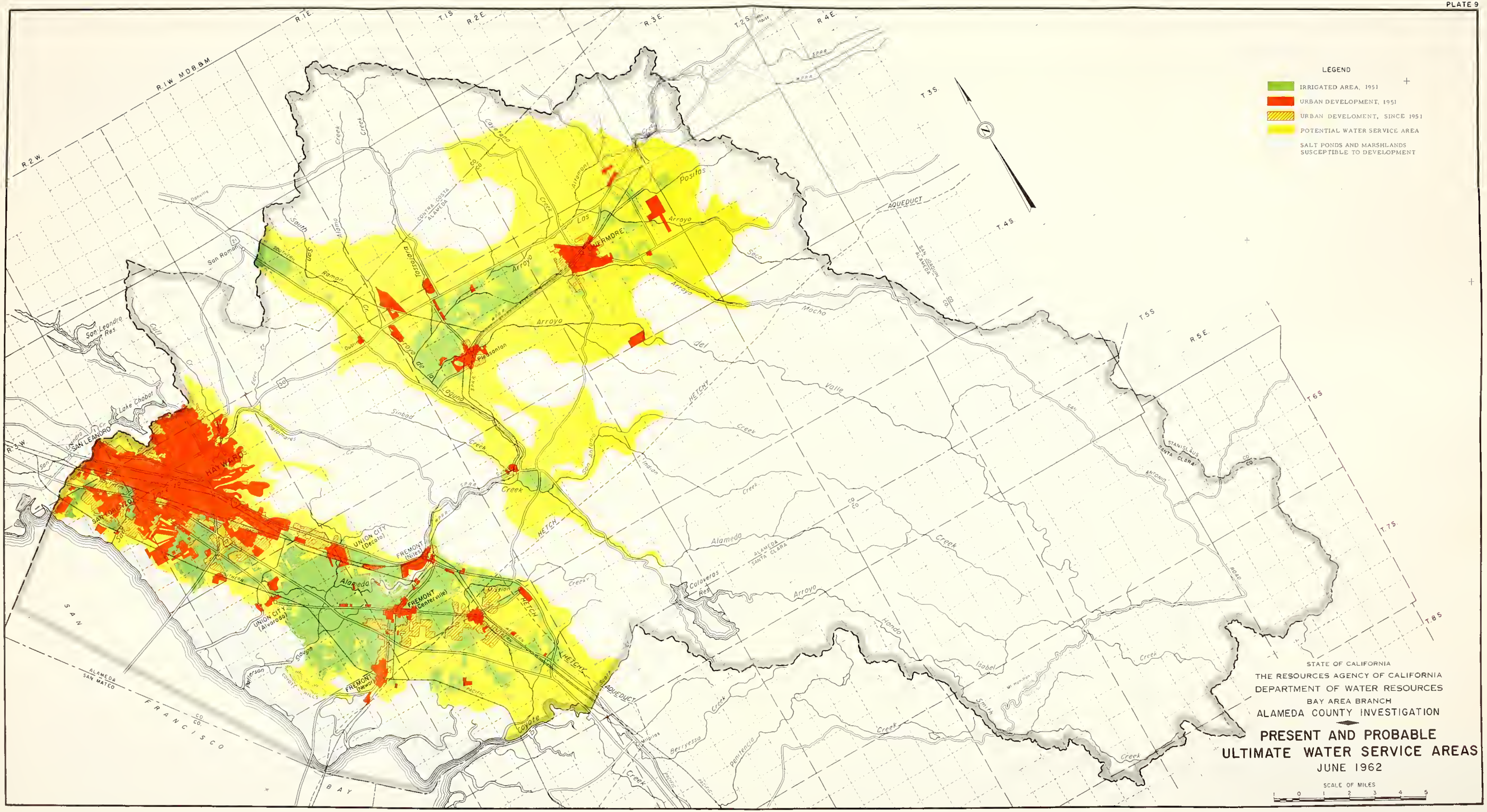

INDEX TO GEOLOGIC MAPPING
(MOST SOURCES MODIFIED)
GEOLOGIC SYMBOLS
QUATERNARY
TERTIARY
CRETACEOUS
JURASSIC
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
AREAL GEOLOGY
JUNE 1962
SCALE OF MILES
2 0 2 4
LIVERMORE
HAYWARD
SAN LEANDRO
SAN LORENZO
PLEASANTON
FREMONT (Centerville)
FREMONT (Niles)
FREMONT (Newark)
UNION CITY (Alvarado)
SAN FRANCISCO BAY
R.1 W. M.D.B.&M.
R.2 W.
R.3 W.
R.1 E.
R.2 E.
R.4 E.
R.5 E.
T.1 S.
T.3 S.
T.4 S.
T.6 S.
T.7 S.

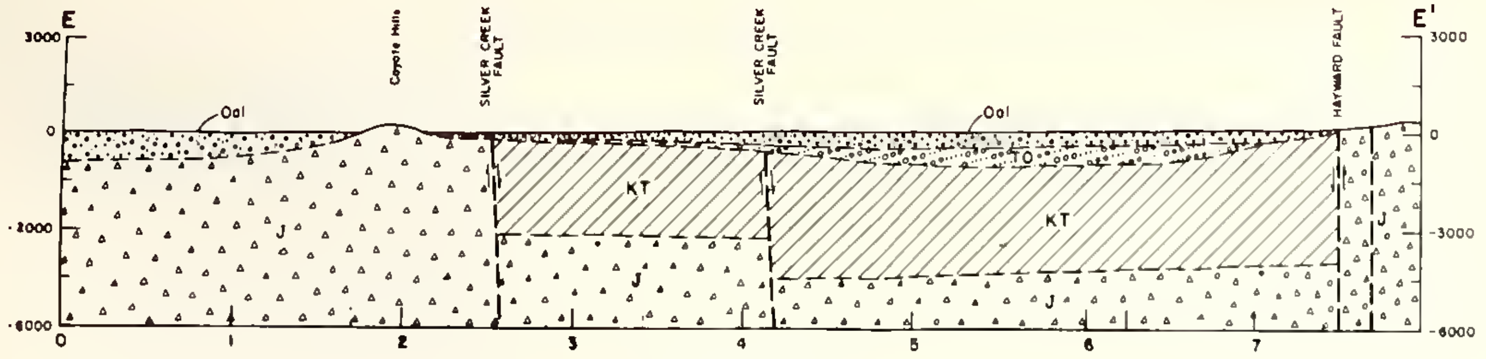


STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION

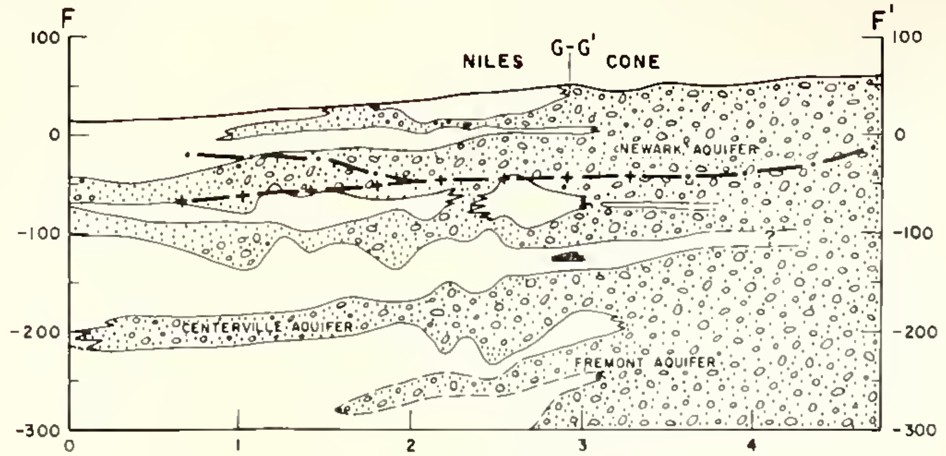
MINERAL CHARACTERISTICS
OF
GROUND WATER
IN
AREAS OF DEGRADATION
JUNE 1962

PLATE 9

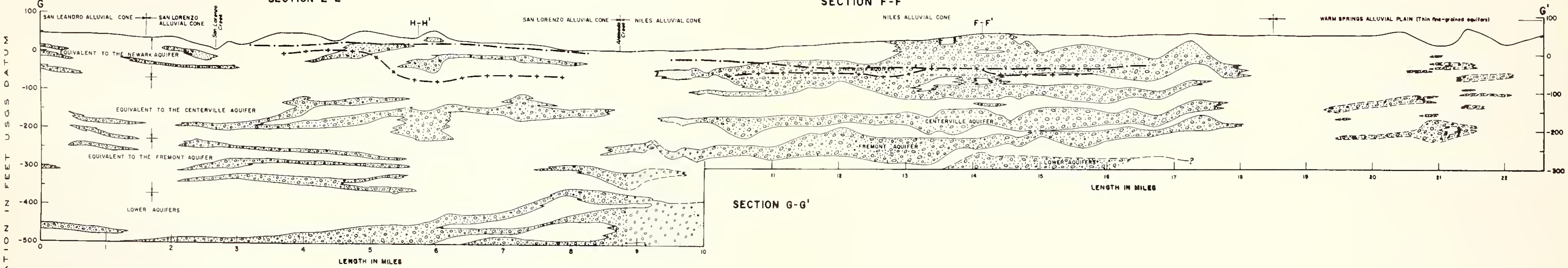

LEGEND
IRRIGATED AREA, 1951
URBAN DEVELOPMENT, 1951
URBAN DEVELOMENT, SINCE 1951
POTENTIAL WATER SERVICE AREA
SALT PONDS AND MARSHLANDS SUSCEPTIBLE TO DEVELOPMENT
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION
PRESENT AND PROBABLE
ULTIMATE WATER SERVICE AREAS
JUNE 1962
SCALE OF MILES
1 0 1 2 3 4 5
HAYWARD
SAN LEANDRO
LIVERMORE
Pleasanton
UNION CITY (Decoto)
UNION CITY (Alvarado)
FREMONT (Niles)
FREMONT (Centerville)
FREMONT (Newark)
SAN FRANCISCO BAY
AQUEDUCT
HETCH HETCHY
Calaveras Res
Lake Chabot
San Leandro Res



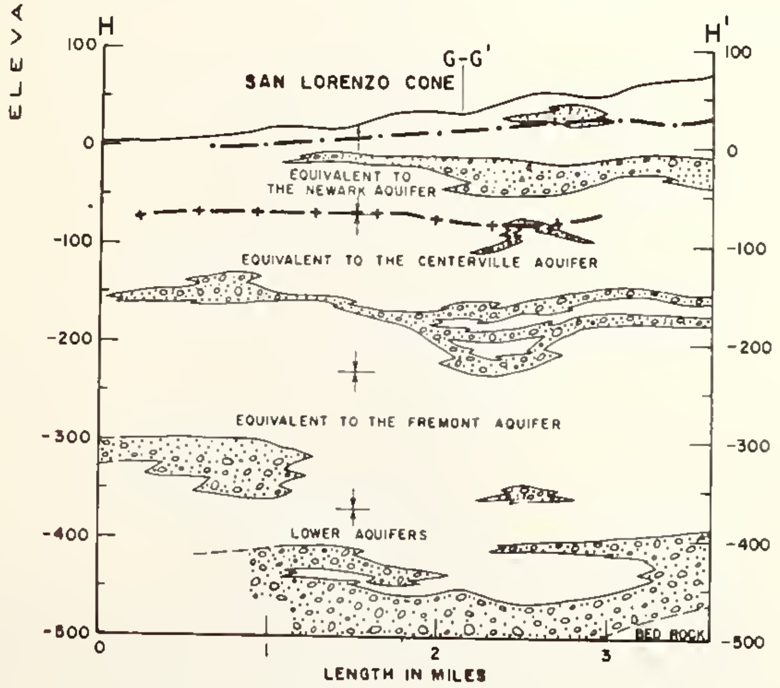
SECTION E-E'



SECTION F-F'



SECTION G-G'



SECTION H-H'

LEGEND

STRATIGRAPHIC SYMBOLS FOR SECTION E-E'

- Qal — LATE QUATERNARY ALLUVIUM. } WATER BEARING DEPOSITS
- TQ — TERTIARY - QUATERNARY SANTA CLARA GRAVELS. } WATER BEARING DEPOSITS
- KT — CRETACEOUS AND TERTIARY ROCKS UNDIFFERENTIATED. } NON - WATER BEARING DEPOSITS.
- J — JURASSIC ROCKS } NON - WATER BEARING DEPOSITS.

LITHOLOGIC SYMBOLS FOR SECTIONS F - F' TO H - H'

- GRAVEL OR SAND AND GRAVEL (AQUIFERS).
- SAND (AQUIFERS)
- CLAY, SILT, SANDY CLAY (AQUICLUDES)
- CONTACT, DASHED WHERE APPROXIMATELY LOCATED.
- FAULT, SHOWING DIRECTION OF RELATIVE MOVEMENT.
- WATER LEVEL IN WELLS TAPPING NEWARK AQUIFERS, SPRING 1961.
- WATER LEVEL IN WELLS TAPPING DEEPER AQUIFERS, SPRING 1961.

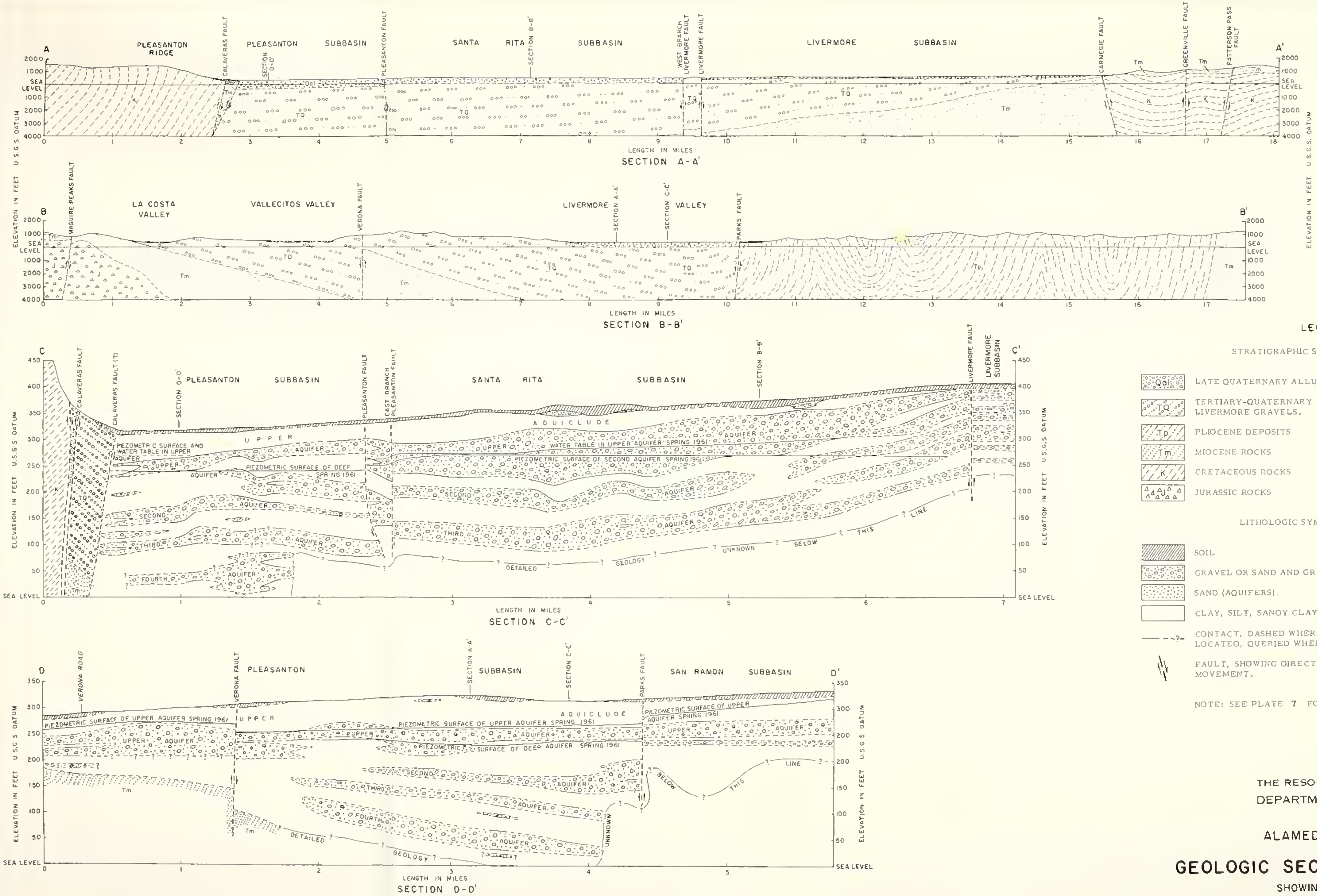
NOTE: SEE PLATE 7 FOR LOCATION OF SECTIONS.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH

ALAMEDA COUNTY INVESTIGATION

GEOLOGIC SECTIONS - BAY PLAIN

SHOWING STRATIGRAPHIC RELATIONS, STRUCTURE AND LITHOLOGY



LEGEND

STRATIGRAPHIC SYMBOLS FOR SECTIONS A-A' TO C-C'

- Qal — LATE QUATERNARY ALLUVIUM } WATER BEARING DEPOSITS
- TQ — TERTIARY-QUATERNARY LIVERMORE GRAVELS. } WATER BEARING DEPOSITS
- Tp — PLIOCENE DEPOSITS } NON-WATER BEARING DEPOSITS
- Tm — MIOCENE ROCKS } NON-WATER BEARING DEPOSITS
- K — CRETACEOUS ROCKS } NON-WATER BEARING DEPOSITS
- J — JURASSIC ROCKS } NON-WATER BEARING DEPOSITS

LITHOLOGIC SYMBOLS FOR SECTIONS C-C' TO D-D'

- SOIL
- GRAVEL OR SAND AND GRAVEL (AQUIFERS).
- SAND (AQUIFERS).
- CLAY, SILT, SANDY CLAY (AQUICLUDES).
- CONTACT, DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN.
- FAULT, SHOWING DIRECTION OF RELATIVE MOVEMENT.

NOTE: SEE PLATE 7 FOR LOCATION OF SECTIONS

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
BAY AREA BRANCH
ALAMEDA COUNTY INVESTIGATION

GEOLOGIC SECTIONS - LIVERMORE VALLEY

SHOWING STRATIGRAPHIC RELATIONS, STRUCTURE AND LITHOLOGY

DEPARTMENT OF WATER RESOURCES 1962